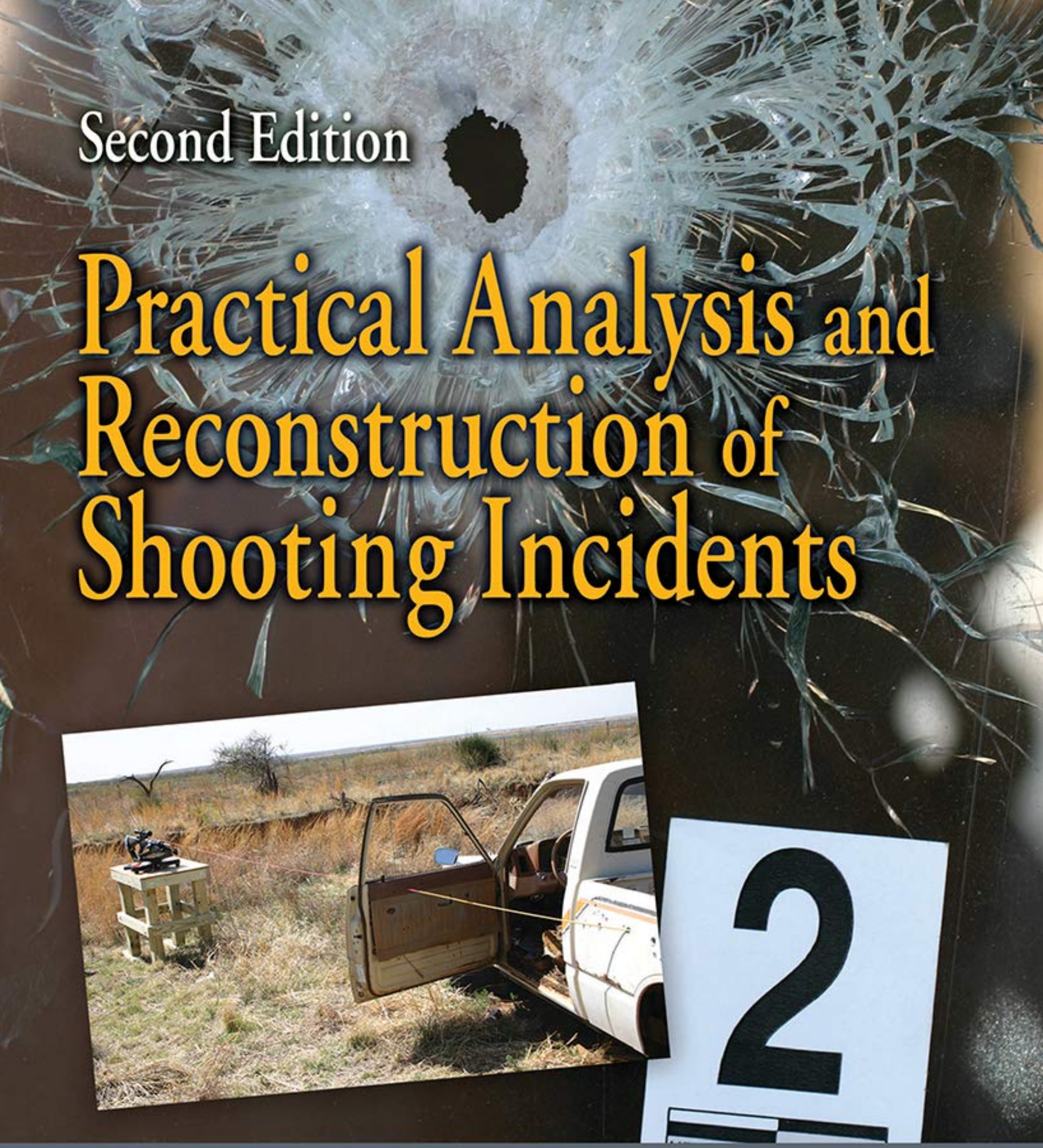
Second Edition

Practical Analysis and Reconstruction of Shooting Incidents



Edward E. Hueske

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Contents

Series Editor Note xv
Preface xvii
Acknowledgments xix
About the Author xxi

1 Terminology: Its Use and Abuse—"The Devil Is in the Details" 1

Ammunition Components 1
Rule #1: Call It What It Is 7
Firearms 8
Other Misused Terms 9
Suggested Readings 13

2 Shooting Reconstruction Myth Busters 15

Bullets and Newton's Third Law 15
Bullets and Intermediary Targets 17
  Case 1 18
    Evaluation 19
  Case 2 19
    Evaluation 20
  Case 3 20
    Evaluation 20
  Summary 21
Bullet and Shot Pellet Ricochets 21
Shotgun Wads, Cups, and Wrappers 23
Gunshot Residues 23
  Case 1 24
    Evaluation 24
  Case 2 24
    Evaluation 24
  Case 3 25
    Evaluation 25
  Case 4 25
    Evaluation 25
Cartridge Case Ejection 25
  Case 1 26
    Evaluation 26
  Case 2 27
    Evaluation 27

Blood Back Spatter from Gunshots 27
Reference 29
Suggested Readings 29

3 Theory and Practice of Shooting Reconstruction 31

Shooting Reconstruction and the Scientific Method 31
  Defining the Problem 32
  Making Observations 32
  Formulate a Theory 32
  Test the Theory 33
  Modify the Theory as Required 33
On-Scene Evidence Evaluation/Documentation 33
Off-Scene Evaluation and Documentation 35
Goal of Shooting Reconstruction 37
Limitations of Shooting Reconstructions 38
Reenactment in Shooting Reconstructions 38
  Full-Scale Reenactments 39
  Scale Models 41
  Case Study 43
  Computer Animation 44
  Time Line Development 44
    Dried/Drying Blood 46
    Clotted Blood 46
    Rigor Mortis (the Stiffness of Death) 46
    Livor Mortis (the Color of Death) 46
  Case Study 47
Other Body Indicators 47
Other Scene Indicators 48
  Case Study 48
Reference 53
Suggested Readings 53

4 Mathematics of Shooting Reconstruction 55

Trigonometry, Geometry, and Shooting Incident Analysis 55
Calculation of Impact Angles 62
Other Calculations 66
Suggested Readings 74

5 Firearms and Ammunition Components 75

Firearms Categories and Nomenclature 75
Special Notes Concerning Firearms 86
  Random Notes about Handguns 86
  Random Notes about Rifles 88
  Random Notes about Shotguns 88
  Random Notes about Submachine and Machine Guns 89

Ammunition Components 89
Scene Documentation of Weapons 94
Suggested Readings 98

6 Shooting Reconstruction Equipment and Its Use 99

Documentation of Bullet Holes at Shooting Scenes 99
Trajectory Rods and Their Use at Shooting Scenes 111
  Bullet Hole Basics 116
  Types of Trajectory Rods 116
  Trajectory Rod Accessories 118
Other Equipment Required 119
  Substrate Considerations 120
  Proper Trajectory Rod Placement 120
  Uneven, Curved Surfaces 120
  Rod "Extension" via Laser 122
  Use of Lasers, Strings, and Adhesive Dots 122
  Key Points to Remember 123
Laser Measuring Devices 127
Total Data Stations 128
3-D Laser Scanners 128
Chronographs 130
Specialized Fixtures for Shooting Reconstruction 132
Camera Equipment for Shooting Reconstruction 135
Suggested Readings 142

7 Smart Phone/Pad Apps for Shooting Reconstruction 143

Plumb Bob App 143
Compass App 143
Angle Gauge App 144
Scientific Calculator App 145
Level App 145
Global Positioning System App 146
Measuring Apps 147
Flashlight App 151
Other Useful Specialty Apps 152
Other Visual Aids 153

8 Cartridge Case Ejection Pattern Testing for Semiautomatics 155

Testing Considerations 155
Methodology 161
Interpretation of Results 164
Suggested Readings 166

9 Shotgun Pattern Testing and Evidence Evaluation 167

Approximating Muzzle-to-Target Distance 173
Angle of Impact Estimation 176

Test Firing 177
Graphical Analysis 178
Shot Shell Buffer and Distance Estimation 178
Reporting of Results 180
Suggested Readings 186

10 Examination/Testing of Weapons and Ammunition Components 187

Trace Evidence Examination 187
 Function Testing 191
Accuracy Determination 194
Rate of Fire Determination 195
Suggested Readings 197

11 Gunshot Residue Testing 199

GSR Sources 199
Persistence of Primer Residue 199
Primer Residues and Shooter Determination 200
Muzzle-to-Target Distance Approximation Testing—Inanimate Objects 206
Collection of GSR from Fixed Inanimate Objects 212
Muzzle-to-Target Distance Approximation Testing—Human Tissue 213
"Paraffin" Test 217
Determination of Time since Discharge 217
Case Study 218
Suggested Readings 222

12 Bullet Hole and Wound Characteristics 223

Bullet Holes in Clothing and Underlying Tissue 223
Reconciling Bullet Holes in Clothing with Underlying Wounds 231
Bullet Holes in Glass and Glass Injuries 235
 Glass Evidence Checklist 246
Bullet Holes in Tires and Other Elastic Materials 247
Documentation 249
Case Study 251
Suggested Readings 256

13 Bullet Ricochet Phenomena 259

Ricochet Terminology 259
Conditions Conducive to Ricochets 259
Directionality Based on Point of Impact 261
Other Indicators of Directionality 261
 The "V" Shape 261
 Fracture Lines in Painted Surfaces 262
 "Classic" Ricochet Mark 264
 The "Pear" Effect 265

Ricochet Crease Profiles 266
  Ricochet with Partial Penetration 267
  Internal Ricochet 267
  Ricochets off Glass 268
Direction of Twist Determination from a Ricochet Mark 270
Establishing Critical Angles 273
Establishing Ricochet Angles 274
Establishing Deflection Angles 275
Establishing Shooter Position 276
Documentation 276
Evidence That a Ricochet Has Occurred 276
Case Study 277
Suggested Readings 284

14 Bloodstains and Blood Spatter at Shooting Scenes 287

Blood Characteristics and Drop Formation 287
Blood Spatter Associated with Firearms Injuries 293
Blood on/in Weapons 296
Blood on the Hands of the Shooter 297
Blood on Objects at the Shooting Scene 298
Nongunshot Dynamics That Can Mimic High-Velocity Impact Blood Spatter 299
Blood and Its Use in Time Line Development 301
Case Study 303
  Production of Pseudo-Impact Blood Spatter 303
Locating Latent Bloodstains 307
Suggested Readings 310

15 Officer-Involved Shootings 311

General Considerations 311
  Protocol for Officer-Involved Shootings 311
Unintentional Discharge of Weapons 318
Accidental Discharge of Weapons 323
Suicide by Cop 324
Case Studies 325
  A Probable Case of Suicide by Cop 325
  Charles Whitman and the University of Texas Tower Incident 331
Why Is the Suspect Shot in the Back? 337
Suggested Readings 339

16 Case Analysis 341

General Considerations 341
Shot Accounting 344
Recognizing Staged/Misrepresented Crime Scenes 348
Off-Scene Analysis of Crime Scene Data 351
Homicide versus Suicide Issues 352
Participant Information to Obtain 353

Shots Fired into Vehicles 354
    Vehicle Bullet Hole Documentation and Trajectory Analysis 356
General Case Analysis Examples 357
    Case 1. Accidental Shooting or Homicide? 357
    Case 2. Homicide or Suicide? 364
Reference 370
Suggested Readings 370

17 Ballistics 373

Internal Ballistics 373
    Gun Powder Considerations 376
External Ballistics 381
    External Ballistics Terminology 382
Terminal Ballistics 387
    Terminal Ballistics Terminology 387
    Common Misconceptions Regarding Wound Ballistics 390
Sound Suppressors 392
    Makeshift Sound Suppressors 393
Case Studies 394
    Case 1. A Homicide Case Involving a Suppressor (“Silencer”) 394
    Case 2. A Case Requiring External Ballistics Study 395
        The Prosecution Theory 396
        The Defense Theory 396
        The Trial 396
Suggested Readings 398

18 Firearm/Ammunition Reference Collections, Databases, and Software 401

Weapons/Ammunition 401
Vehicle Information 403
Architectural Information 406
Weather and Meteorological Data 407
Imagery 409
Crime Scene Software 410
Suggested Readings 411

19 Report Writing, Demonstrative Evidence, and Courtroom Presentation 413

Report Format 413
    Suggested Summation Report Format 414
Drawings, Diagrams, and Photographic Images 415
    General Rules for Shooting Scene Photography 415
    General Considerations in Shooting Scene Diagramming 420
    General Videotaping Protocol for Shooting Scenes 423
Full-Scale Reproductions 424

PowerPoint Presentations 425
  Considerations for Courtroom PowerPoint Presentations 426
  Photoshop in Reports and Court Testimony (Contributed by NYPD Detective Sergeant [ret.] John Paolucci) 426
Court Testimony 428
  Courtroom Presentation Basics 429
Trial Presentation and Demonstrative Evidence 429
  Different Types of Evidence 430
  Kinds of Demonstrative Evidence 430
Suggested Readings 440

20 Maximizing Crime Laboratory Results 443

Failure to Request Appropriate Analyses 443
  Case Example 443
Failure to Provide Pertinent Details 446
  Case Example 446
Failure to Collect Appropriate Samples/Controls 447
  Case Example 447
  Case Example 447
Summary 448
Suggested Readings 448

Glossary 449

Appendix A: A Ballistics Fable 455

Appendix B: Ammunition Component and Related Terminology 457

Appendix C: Scientific Working Group on Bloodstain Pattern Analysis—Recommended Terminology 465

Index 469

Series Editor Note

This textbook is part of a series titled “Practical Aspects of Criminal and Forensic Investigation.” This series was created by Vernon J. Geberth, a retired New York City Police Department lieutenant commander who is an author, educator, and consultant on homicide and forensic investigations.

This series has been designed to provide contemporary, comprehensive, and pragmatic information to the practitioner involved in criminal and forensic investigations by authors who are nationally recognized experts in their respective fields.

Preface

Forensic science, simply stated, is the application of science to the judicial system. The subdiscipline of forensic science most directly involved in the analysis and reconstruction of shooting incidents is criminalistics. Criminalistics is the study of physical evidence—things that one can typically see, touch, or smell (e.g., hairs/fibers, bloodstains, gunpowder residue, footwear impressions, firearms, and tool marks). The analysis and reconstruction of a shooting incident are much like putting a jigsaw puzzle together with the various types of physical evidence representing pieces of the puzzle. When there are missing pieces to a jigsaw puzzle, it can be very frustrating trying to complete the puzzle. The same frustration can arise in shooting reconstruction efforts wherein there are gaps in the associated physical evidence. Thus, a thorough, meticulous approach beginning at the crime scene and continuing through the subsequent off-scene investigative efforts is paramount to a successful outcome.

A catchphrase the author has used in his classes on crime scene investigation over the years is, "In a crime scene investigation you can only get out of it what you put into it." Like many other endeavors in life, the results achieved are directly related to the degree of effort put in. A classic example is given by a very high profile case the author was involved in many years ago involving the abduction and murder of a young girl. Because the scene encompassed several acres of hilly, rugged terrain, police investigators elected to do their initial search for the child's body via four-wheel all-terrain vehicles. As it turned out, the investigators failed to find the body even though they rode right by it and did not locate it until several days later when a proper search was conducted on foot. The lost time in the interim allowed further deterioration of the child's remains as well as possible loss of physical evidence.

The guiding principle for any crime scene investigation should be to do everything reasonable in pursuit of pertinent evidence. The distinction between what is reasonable and what is unreasonable with regard to scene investigation is usually obvious. For example, let us suppose that a shooting scene investigator has reason to believe that one or more bullets may be lodged in the wooden floor beneath the carpet in a living area inside a house. In order to attempt to locate any bullets that might be beneath the carpet, the investigator tries using a metal detector but quickly finds that nails, metal braces and metal pipes make the effort an exercise in futility. At this point, the only alternative is to remove all the furniture and pull the carpet and look for visible evidence of bullet entry, an arduous task for sure. But is it unreasonable to do so? I say no, it is not unreasonable at all.

A case in point from past years involved just such a scenario. As it turned out, the bullets in the floor had been fired by officers who had been involved in a shootout inside a residence. After the involved police department had released the scene, an expert for the plaintiffs in what became a civil suit against the department came in and recovered two fired bullets from the floor. Those two bullets were the centerpiece of an alleged conspiracy on the part of the police according to the expert. The author became involved as the defendant's (the department's) expert, and it required significant time and effort to counter the allegations that arose as a result of not locating and collecting all the fired bullets at the scene.

All of this boils down to the fact that the most important aspect of a shooting scene investigation is usually the initial on-scene effort. If it is not done right, it is unlikely that an investigator will get a second chance to go back to a scene. The individual charged with the location, preservation, and documentation of crime scene evidence can make or break a case. The individual or individuals responsible for the off-scene analysis and reconstruction efforts must rely on those who processed the scene. The most astute shooting reconstruction expert can seldom rise above the level of the evidence provided by the scene investigator.

Likewise, the world's greatest crime laboratory can only work with that which is provided them by the scene investigator. A very appropriate crime laboratory cliché comes to mind: "Garbage in equals garbage out."

Although it is unlikely that crime scene investigators will be called upon to reconstruct a shooting incident at trial, their efforts pretty much control what can be concluded as to the who, what, when, where, and how of the crime. Accordingly, it is incumbent upon the crime scene investigator to adopt a "reconstruction mentality." What is meant by that term is constant thought must be given by the scene investigator as to how each particular piece of evidence might play into the overall crime. As the author has repeatedly pointed out in training classes, not to do so relegates scene investigators into the role of "forensic garbage collector" rather than the professional they should be aspiring to be. It is worth repeating again for emphasis: The scene investigator has the most important job of all in the analysis and reconstruction of shooting incidents.

The court presentation of a shooting incident reconstruction is frequently a "team effort" that involves scene investigators, detectives, the pathologist, and criminalists "choreographed" by the prosecution or the defense (usually both sides will prepare their "version" of a shooting incident). In other instances, one expert in shooting incident reconstruction is used to interpret and present all the findings to the jury, either on behalf of the prosecution or the defense. Shooting incident reconstruction experts must have a broad background in criminalistics and be well grounded in the application of the scientific method. Although it is not essential that individuals who hold themselves out to be a shooting incident reconstruction expert be a forensic scientist, it is clearly a desirable credential.

Acknowledgments

This second edition of *Practical Analysis and Reconstruction of Shooting Incidents* is dedicated to the many law enforcement professionals who have attended my shooting incident reconstruction classes over the past 25 years and who, through their insightful questions and observations, have motivated me to find answers to their questions and to further develop related analytical techniques. I should hasten to point out that I have never failed to come away from one of my own classes not having learned something from those in attendance. Since the publication of the first edition in 2006, a number of new techniques have been developed and many new ideas concerning well-established techniques have likewise arisen. The primary goal of this second edition is to share this knowledge with all who have an interest in this challenging endeavor. As I like to state at the beginning of each of my shooting reconstruction classes, "I certainly don't know all there is to know about this subject but I have learned a few things over the years and I would like to share them with you."

None of this would have been possible were it not for the many sacrifices made by my dear wife of nearly 50 years, Gretchen, and our children and grandchildren—all of whom have frequently had to endure my absences from family activities as I have pursued my other love—shooting incident reconstruction. I am greatly appreciative of the special contributions of several friends and colleagues who have shared their knowledge and provided some really neat stuff for this edition: Max Courtney of the Mansfield Police Department here in Texas has been my friend and mentor from the day I set foot in a crime laboratory back in 1974. Max provided the special section on demonstrative evidence for this text. Dr. Bob Taylor, now a resident of Bend, Oregon, has been a great friend and someone whom I have always been able to count on concerning police policies and procedures as well as the whole arena of criminal investigation. Dr. Charles Heller of Blinn College personifies the word "friend" and has always been willing to share his knowledge of theoretical chemistry and basic physics when some issue relating to my endeavors in shooting reconstruction has come up. Michael Haag of the Albuquerque Police Department has been gracious enough to share some of his pioneering work in the area of 3-D laser imaging. Detective Sergeant John Paolucci, New York Police Department (ret.), contributed the really great example of the use of Photoshop in reports and court presentations. There are many others without whose help this second (and quite likely last) edition would not have been possible. It has been a great journey folks, thanks to you all (or, as we Texans say, "Thanks y'all").

About the Author

Edward E. Hueske began his career in forensic science in 1974 at the Fort Worth Police Department Criminalistics Laboratory following a 3-year stint as a chemistry instructor at Blinn College in Brenham, Texas. As someone who grew up around guns, it was a natural progression into forensic firearms identification and shooting incident reconstruction. Even after advancing into crime laboratory management positions in Texas and later in Arizona, he continued to do casework in forensic firearms and shooting incident reconstruction. Following his retirement in 1996 from government crime laboratory service, he established Forensic Training & Consulting, LLC, which he continues to operate. Over the past 25 years, the author has provided specialized training to hundreds of individuals from local, state, and federal law enforcement agencies, primarily in the area of shooting incident reconstruction. He has taught both domestically and abroad, having provided training to such diverse agencies as the Federal Bureau of Investigation, the Drug Enforcement Administration, the Texas Rangers, the New York City Police Department, the Montana Criminal Investigation Division, the Turkish National Police, the Guatemala Attorney General's Office, and the Royal Canadian Mounted Police.

In 1999, Hueske joined the faculty of the University of North Texas in Denton, Texas, where he set up and taught in an undergraduate certificate program in criminalistics through the Department of Criminal Justice. He also taught graduate school–level criminalistics courses and completed the first edition of this text, as well as published a text designed to introduce high school and community college students to forensic science.

Hueske has published more than 40 papers in the forensic literature and continues to conduct applied research in the area of shooting incident reconstruction.

He is a distinguished member of the Association of Firearm & Tool Mark Examiners, a fellow of the American Academy of Forensic Sciences, and an emeritus member of both the American Society of Crime Laboratory Directors and the Southwestern Association of Forensic Scientists. He is also a member of the International Association of Bloodstain Pattern Analysts.

Terminology: Its Use and Abuse

"The Devil Is in the Details"

1

Ammunition Components

An ongoing issue that continues to persist is the misuse of terminology by individuals outside the field of forensic science who utilize the results provided by forensic scientists: police investigators, prosecutors, defense attorneys, the media, and the general public. This terminology misuse results in confusion and misunderstanding on the part of everyone involved. The root cause of terminology misuse is the perpetuation of colloquialisms at every level, save for the forensic scientist. Without a doubt, the most commonly misused term relating to firearms is "bullet," when the actual reference being made is to a cartridge or round of ammunition. Over and over we hear such references being made on the six o'clock news: "The gun was found with four bullets" or in court by an attorney: "How many bullets were in the gun?" or even in a police report: "The gun had no bullets inside."

Seemingly, some might characterize all this as "much ado about nothing" or simply say "Everyone knows what is being referred to." Really? When a forensic firearm examiner is testifying in court and makes the statement "3 fired bullets were recovered at the scene," suffice it to say that most jurors, many prosecutors, and defense attorneys and even judges are thinking that is a reference to fired cartridge cases rather than the projectile portions of cartridges. Equally confusing, if not more so, is when police investigators use the common term "bullet" when testifying in the same court proceeding as forensic scientists who correctly refer to cartridges or rounds of ammunition.

Equally problematic is when a police report is issued with an attached evidence collection inventory that uses incorrect terminology (e.g., "bullet" to refer to cartridges). Individuals who must rely on these reports in reconstructing crimes must ultimately seek out the evidence itself in order to inspect it and determine what exactly was collected. The bottom line here is that, for uniformity and clarity, everyone in the criminal justice community, and members of the media, need to use the same terminology as specified by forensic scientists. Admittedly, that is a tall order but not an effort that the author is ready to throw the towel in on yet. At the very least, law enforcement members need to adopt and use the proper terminology as necessary. The good news is more and more agencies are doing so in the United States.

Other commonly misused/misapplied terms relating to ammunition components include the following:

- "Explosion" when referring to the rapid burning of gunpowder during discharge (firing)
- "Hull" or "casing" when the proper term is cartridge case
- "Spent hull" or "spent casing" when the proper term is fired cartridge case
- "Slug" when referring to anything other than a shotgun slug
- "Wad" when actually referring to a shot cup or wrapper

When a cartridge or shotgun shell is fired in a gun, the gunpowder within the confines of the cartridge case or shotgun shell is ignited and burns rapidly. It does not explode, hopefully, for if that were to happen, the person holding the gun would likely be injured or killed. This expansion of gases does take place extremely rapidly, but it is not an explosion by design, save for the primer. The primer does explode as a result of impact (by the hammer/firing pin and that is what ignites the power).

A term that appears frequently in evidence inventories and crime scene reports is the use of the general term “projectile” for any/all components relating to fired bullets. In cases reviewed by the author on behalf of police agencies over the past 20 years, this has been the typical occurrence. It appears that this “projectile syndrome” is a deeply ingrained aspect of police terminology and is the result of a lack of training. Having said that, a description of proper terminology and the importance thereof is in order. Figures 1.1 through 1.4 illustrate some of these concerns.

The importance of the use of proper terminology and being as specific as possible in describing evidentiary items is exemplified on a regular basis when an individual is tasked with reconstructing the events relating to a shooting incident. The first step in shooting incident reconstruction is shot accounting (this will be explained in detail in a later chapter). Simply stated, this is the determination of the number of shots fired. The author has been and continues to be called upon by police agencies to reconstruct shooting incidents

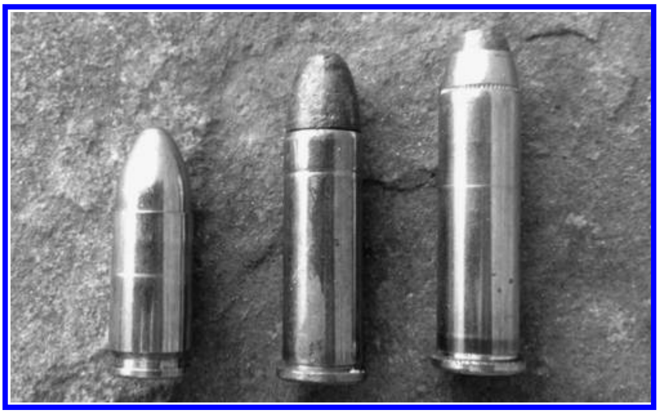

Figure 1.1 Cartridges (live rounds).

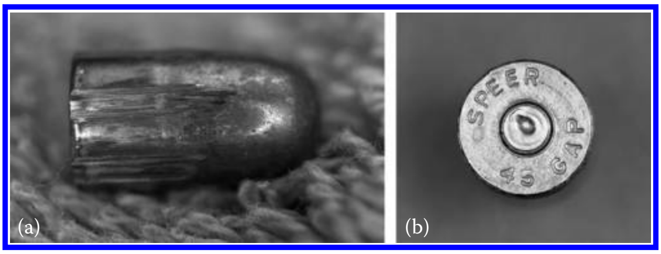

Figure 1.2 (a) Bullet. (b) Fired cartridge case.

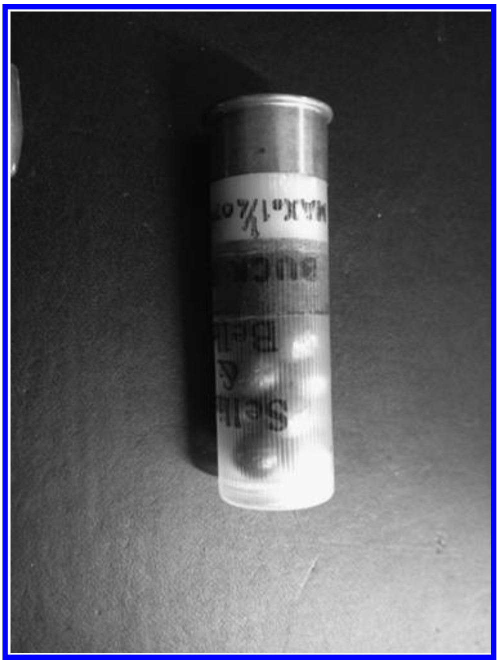

Figure 1.3 See-through 12 ga shot shell.

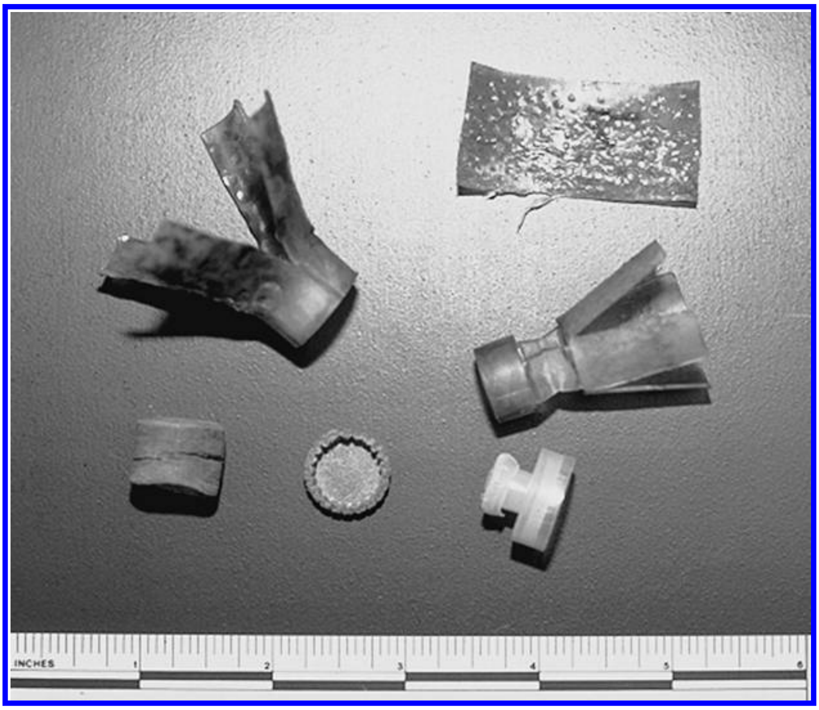
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Figure 1.4 Shot cups, wrapper, and wads.

involving police officers on a regular basis. Part of the shot accounting process involves reviewing the evidence inventory lists and police reports in an effort to determine the number of live rounds, fired cartridge cases, and fired bullets in order to establish the likely number of shots fired. With that goal in mind, take a look at the following excerpt from a police evidence collection log:

Evidence Collection Log

Item #	Location where found	Description	Collected by	Time collected
1	On floor near head of deceased	Projectile	R. Mullins	2130 hours
2	Under night stand in bedroom	Projectile	R. Mullins	2145 hours
3	Wall above headboard in bedroom	Projectile	L. McCready	2136 hours

The obvious question here is, are there three fired bullets, two fired bullets, or just one fired bullet (three fragments of the same bullet)? There is no way to tell from the descriptions (i.e., “projectile”). You say “just look at the crime scene photographs and it can be determined.” Really? What if all the items collected were not photographed? What if some of the photographs do not clearly show what was collected? Moreover, it takes considerable time to acquire and compare photographs to evidence items. Ultimately, the only reliable way to deal with this problem will be to open each evidence packet and examine the contents directly. In the author’s case, this typically means traveling to some distant location and spending a day or two opening packages, all at no small expense.

So what is the real solution to this problem? Train crime scene technicians and anyone else responsible for collecting, packaging, and describing such evidence in the use of appropriate terminology. The following terminology should be learned and used in all documentation related to the evidence collected at a shooting scene:

Cartridge—a complete (unfired) unit consisting of a cartridge case, powder charge, bullet, and primer (either rim fire or center fire)
- Cartridge case (may be fired [as indicated by firing pin impression and interior soot deposits] or unfired—this should be specified in the crime scene investigation report)
- Shotgun shell or shot shell (if fired, there will be a firing pin impression and an open end absent of powder/pellets/slug—correctly referred to as “fired shot shell”)
- Shot cup—plastic component that holds the shot and separates the powder from the shot
- Wad—plastic, paper, or fiber disk that separates the powder from the shot
- Wrapper—piece of flat plastic that surrounds the pellets in a shot shell

Bullet—the projectile portion of a cartridge typically consisting of lead, electroplated lead, or a lead inner core with a copper or brass skin (jacket)
- Fired bullet—bullet with obvious signs of firing (i.e., rifling marks and/or damage/expansion) (Figure 1.5)
- Bullet core—inner lead core from which the jacket has separated (note: there will be no rifling marks present on the core, only on the jacket)

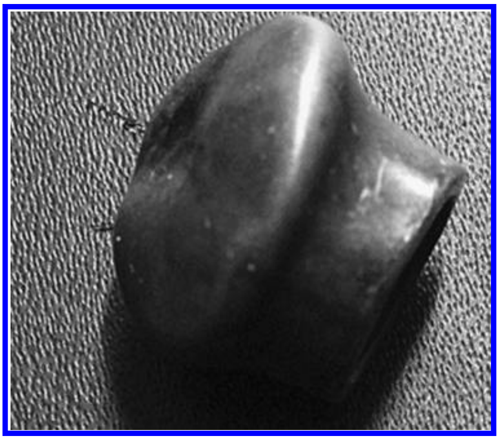


Figure 1.5 Fired bullet.

- Bullet jacket—the copper or brass outer skin of a jacketed bullet (fired bullet jacket will have rifling marks and damage/expansion visible)
- Fragments (i.e., bullet fragment, jacket fragment, core fragment)—obviously incomplete based on size and appearance (Figures 1.6 through 1.8)
- Shot pellets (may be visibly damaged, and if so, describe as such)

Slug—lead projectile designed to be fired in a shotgun (as there is typically no rifling in a shotgun barrel, the slug will frequently have rifling cast into it to impart spin stabilization)

Unidentifiable metal fragment—metallic fragment having no discernible bullet/pellet/slug characteristics (if the surface can be indented/scratched with the thumbnail and is dark gray, it is reasonable to refer to it as an "unidentifiable *lead* fragment")

These terminology issues are illustrated in Figures 1.5 through 1.8.

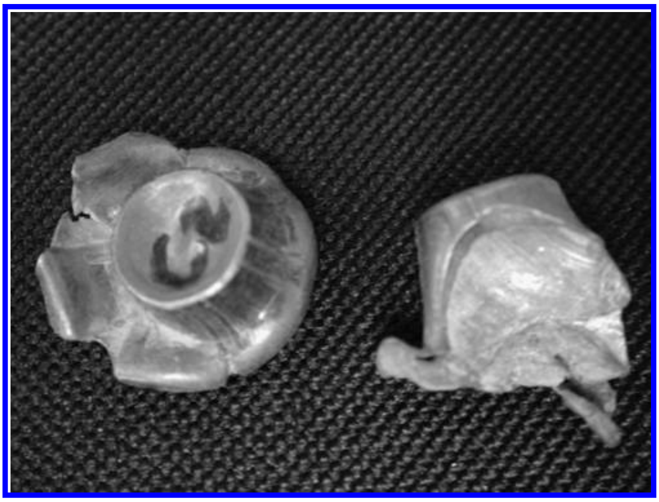


Figure 1.6 Fired bullet fragments.

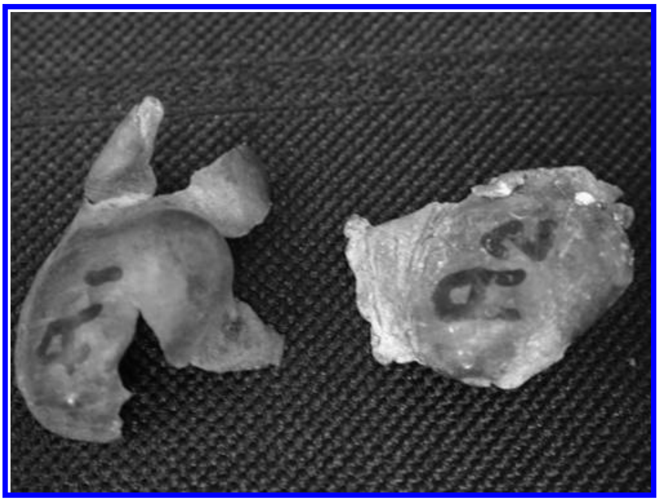


Figure 1.7 Bullet jacket fragment (left); unidentifiable metal fragment (right).

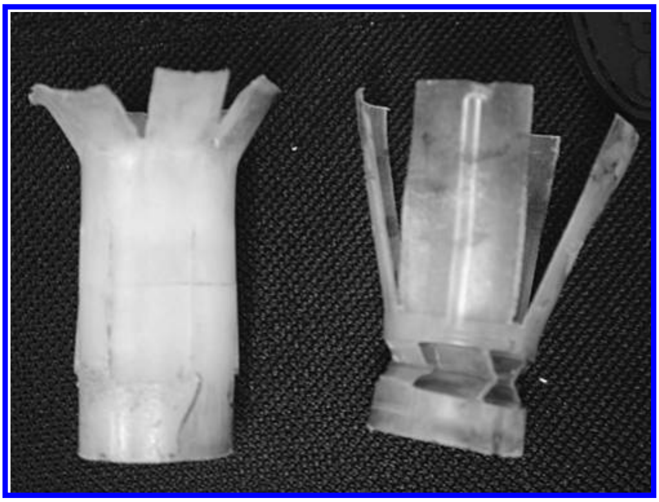


Figure 1.8 Fired shot cups.

The preceding information is, admittedly, somewhat of a departure from the terminology that most non–law enforcement individuals have grown accustomed to and use in normal conversation from time to time. Law enforcement agencies have historically had their own "jargon" that is used. However, the listed terms are the standard terms used by forensic firearm examiners and are being used by more and more criminal justice professionals. The use of slang terms such as "slug" and "bullet" by individuals presenting themselves as professionals in their fields is not in keeping with the professional image they are trying to project, to say nothing of the lost time and resources that such misuse of terms can cause. A simple rule that can be easily remembered is given next.

(i.e., referring to every ammunition item as a "projectile" or misapplying terms such as "bullet" creates confusion and requires later inspection of the evidence item to determine what it actually is.)

Another typically misunderstood term is gunshot residue (GSR). Where the misunderstanding usually comes into play is not recognizing the fact that GSR consists of two distinctly different components: gun powder residues and primer residues. These two components are decidedly different in both compositions and the information that their presence can provide to the shooting reconstructionist. A thorough explanation of the chemistry and physics of these residues will be presented in a later chapter. For purposes of our current discussion of the proper terminology to use, suffice it to say that the following terms are appropriate:

GSR—a general term that includes gunpowder residue AND primer residue (really need to make the distinction as to which is being referred to)
Powder particles—visible residue on clothing or other *inanimate articles* (Figure 1.9)
Powder stippling—abrasions (NOT burns!) on skin produced by gunpowder impact (postmortem stippling appears yellow-brown as opposed to antemortem reddish color) or shotgun shell buffer
Primer residue—deposits of ultramicroscopic spheroid particles containing compounds of barium, antimony, and lead that result from firearms discharge
Soot deposits—dark residue ("smoke") resulting from gunpowder combustion (discharge)
Bullet wipe—black soot/grease ring at the margins of bullet holes through inanimate objects (Figure 1.10)

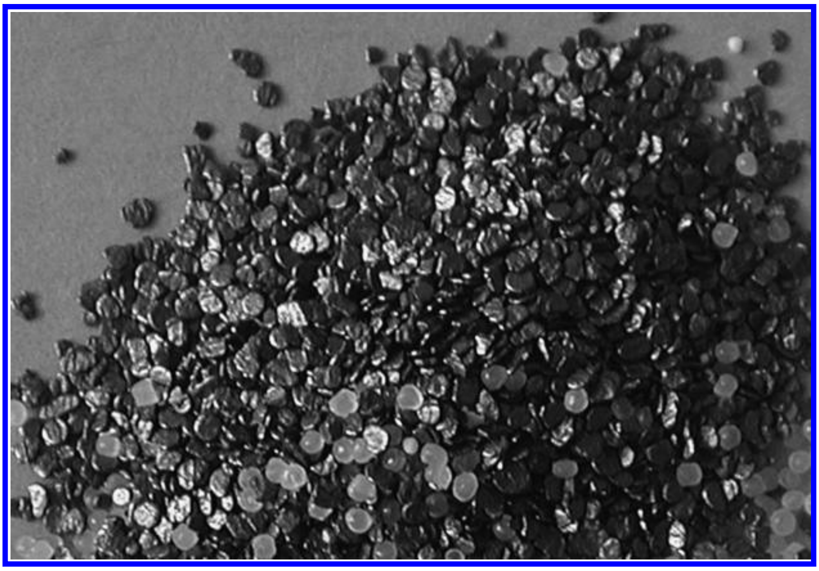


Figure 1.9 Gun powder particles.

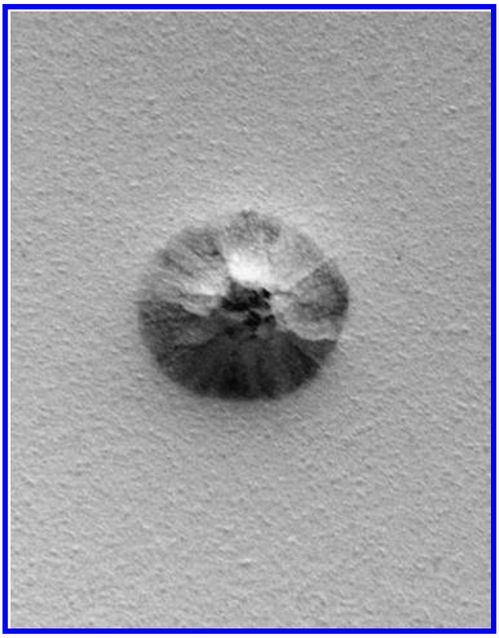


Figure 1.10 Bullet wipe.

A number of years ago, the author was a party to a classic demonstration of the lack of understanding of just what falls under the broad heading of GSR. While being cross-examined by defense counsel in a shooting case, the author was asked "Did you check for GSR?" The author's response was "What particular kind of GSR are you referring to?" After a few moments, the defense attorney replied "The usual kind"—to which the author asked which would that be. Appearing a bit exasperated, the defense attorney then stated, "Let's just move on," ending the discussion of GSR. More often than not, this lack of understanding as to the true composition of gunshot residue and how it might be applied in a particular case has pervaded.

The term "powder burn" is frequently misapplied to both stippling and to soot (smoke) deposits. True, it is possible to get burning or charring from a very close range muzzle blast, but most of the time, particularly in intermediate and long range shots, the use of the term "powder burn" is inappropriate. Figures 1.9 and 1.10 show powder particles and residue left by bullet passage.

Firearms

A number of inappropriate terms are frequently used in reference to firearms. The most misused term is probably "clip" when referring to a magazine. Although there is such a thing as a clip (a metal device that holds cartridges together for ease in placing them into a magazine [a reservoir for holding cartridges])—and although this is not nearly the big deal that some other misapplications of terminology cause—it is, nonetheless, not the best term in reference to modern small arms.

In a case the author reviewed for a police agency, a videotaped interview of the involved officer by his lieutenant was provided for examination. In the interview, the officer clearly used good judgment by not correcting his lieutenant's repeated reference to the "clip" of the officer's pistol even though the officer kept correctly referring to it as a magazine. Again, this was not a tragic mistake by any stretch of the imagination, but the recording did not make the lieutenant sound particularly professional.

Other misused terms that are of the "nonfatal" variety but still detract from the implied professionalism of the user include the term "automatic" when the correct term is semiautomatic and "accidental discharge" when unintentional discharge is appropriate (accidental discharges require a mechanical malfunction, whereas unintentional discharges do not). The term "hair trigger" should only be used when a trigger pull of 1 pound or less is involved.

A commonly misapplied phrase most frequently used by persons involved in shooting incidents is "the gun just went off." In the author's experience, the use of that phraseology seems to reflect a desire on the part of the user to separate themselves from responsibility for the firearm discharge. Clearly, a firearm does not spontaneously discharge without some sort of external force having been applied. Typically, that translates to the trigger having been pulled with the gun cocked and a live round in the chamber.

An admittedly ludicrous example of the misuse of the phrase "the gun just went off" occurred some years ago when the author was contacted by an attorney who stated that his client, who had been charged with murder in a shooting incident, insisted that he was handing a pistol to an acquaintance when it "went off." The client was emphatic that the pistol was lying in his open palm and his finger never touched the trigger when the gun "went off," the bullet striking and killing the acquaintance.

The attorney advised that his client wanted the author to "test" the gun to see if it would spontaneously fire. Somewhat tongue in cheek, the author asked the attorney, "Exactly how do you propose that the testing be carried out?"—to which the attorney replied, "I'll leave that to you." Accordingly, the author placed the cocked gun (loaded with a primed case—no powder or bullet) on a table and monitored it for 8 hours and then conducted drop tests dropping it onto the floor repeatedly from various heights and positions before concluding that the gun not only would not "spontaneously discharge," but would not discharge as a result of being dropped (under the test conditions).

Other Misused Terms

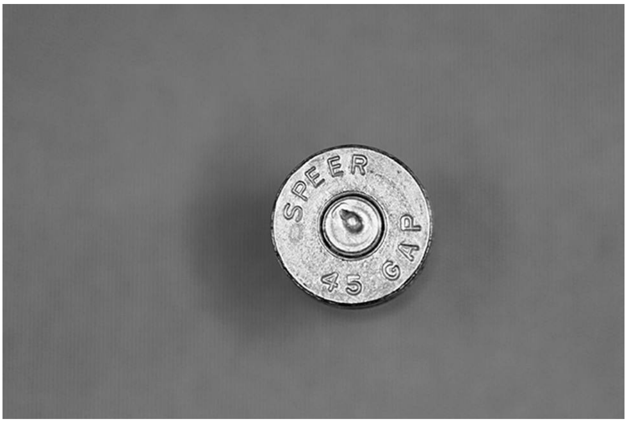
The terms "penetration" and "perforation" are not interchangeable even though they are frequently used as though they are. A bullet that penetrates a substrate enters but does not exit. But over and over, we hear the media refer to a bullet having "penetrated" a car windshield or "penetrated" a residence door or find that terminology used by investigators in written reports and in court testimony. The correct term, although seldom used, is perforation—having both an entry and an exit. The use of the term penetration is correct only when there is no exit (e.g., in the case of a bullet, the bullet enters but does not exit).

Another "used and abused" term is the word laying. Once again, the typical occurrence is to refer to items as "laying" here or there within a crime scene when the correct word is lying. As the author has frequently mentioned in his shooting reconstruction classes: "Chickens lay, evidence lies (by physical location)."

Exercises

Give the appropriate term for each of the following images:

1.



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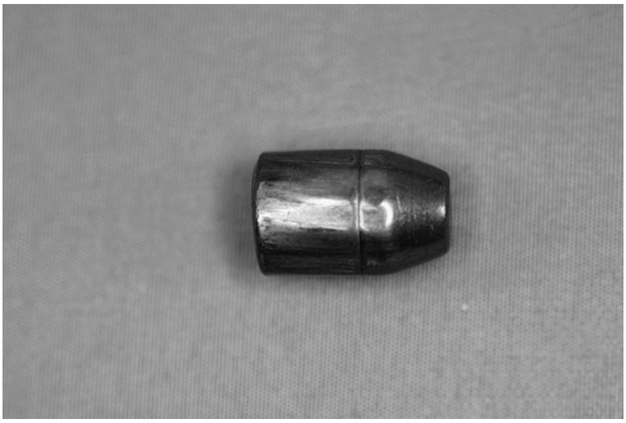

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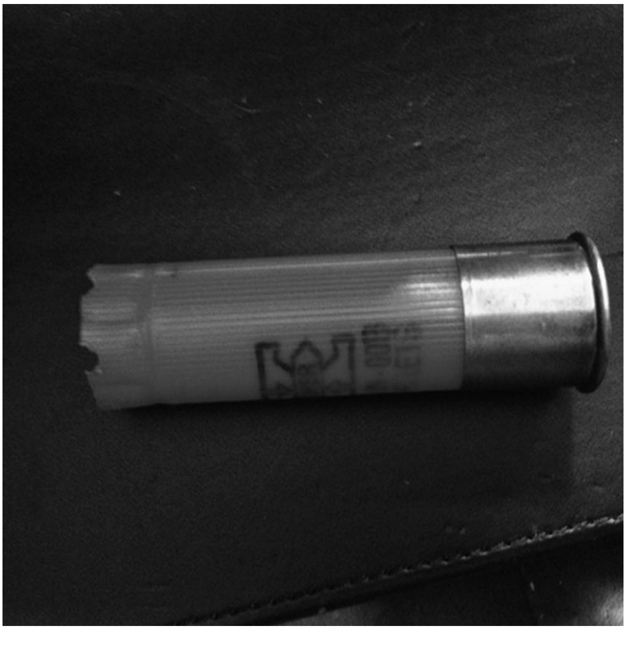

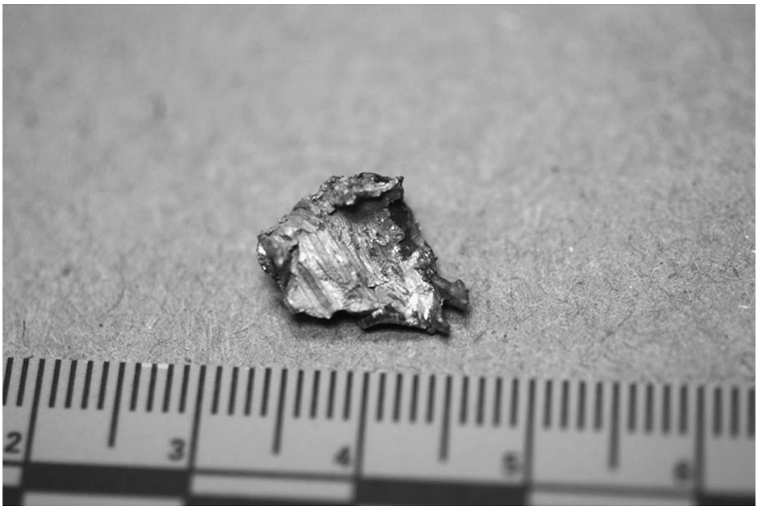

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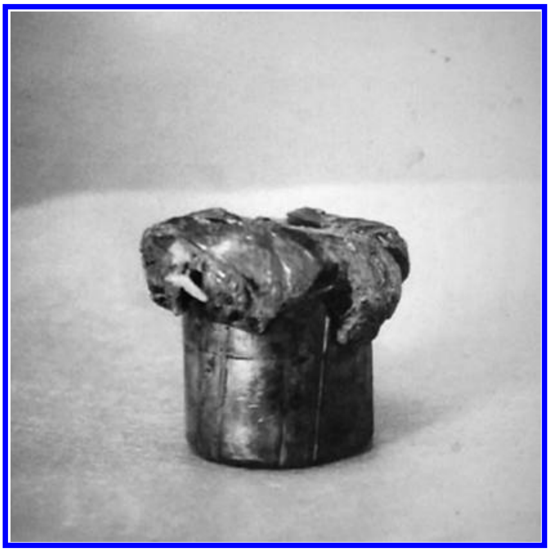

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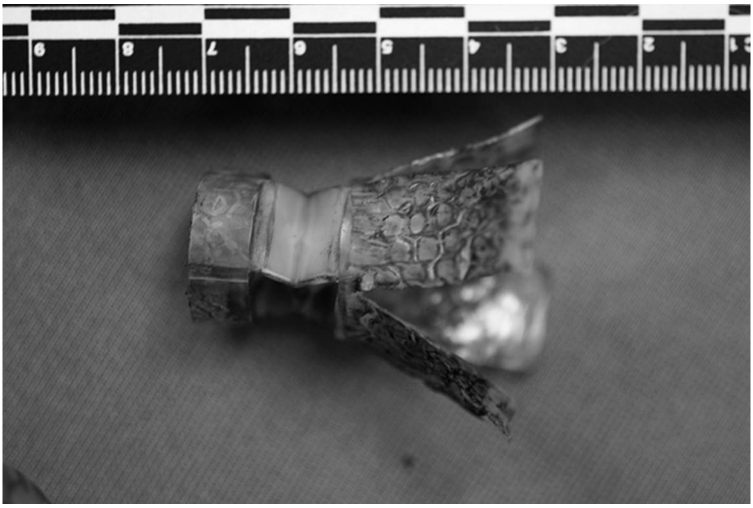

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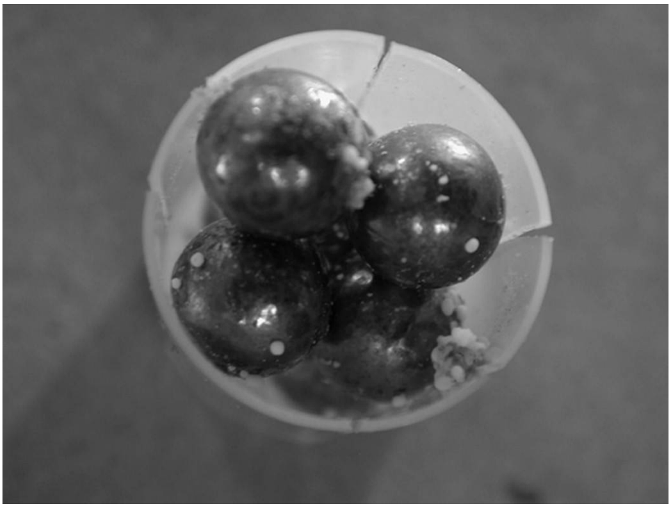

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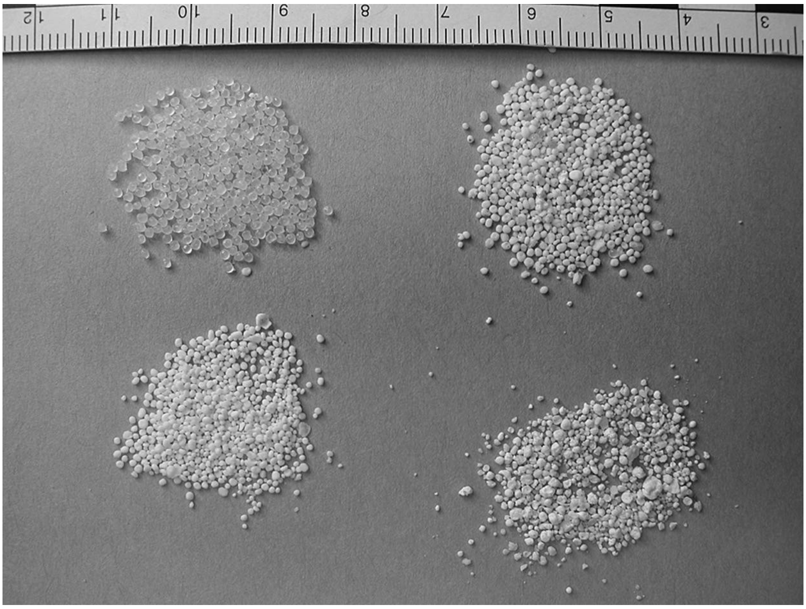

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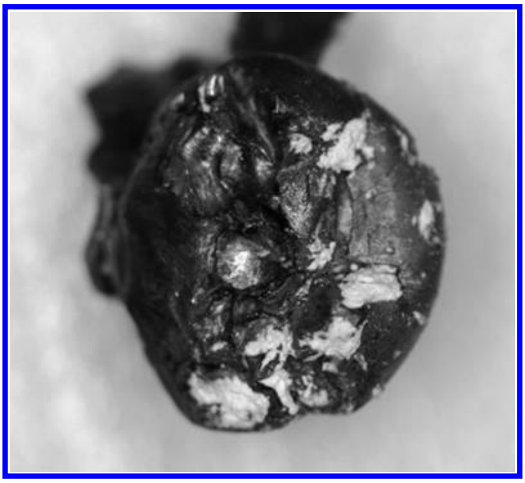
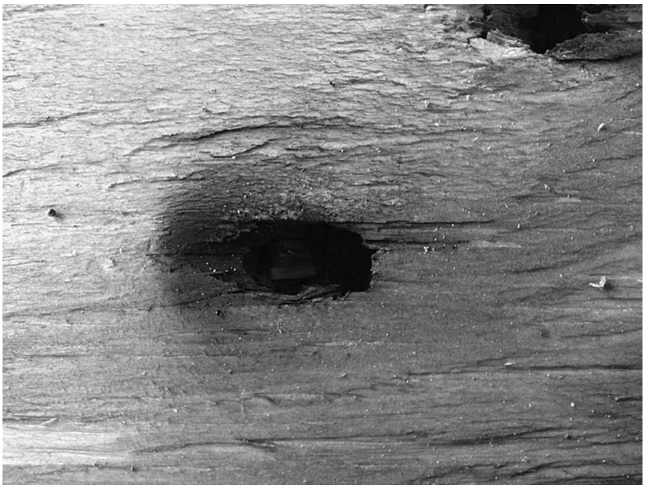


9.

10.



Answers: (1) fired cartridge case, (2) fired bullet, (3) fired shotgun shell, (4) bullet fragment, (5) fired bullet with blue residue, (6) fired shot cup, (7) copper plated shot pellets, (8) shot shell buffer, (9) pulverized glass on fired bullet nose, (10) soot deposit.

Suggested Readings

Association of Firearms and Tool Marks Examiners Glossary (access at http://www.firearmsid.com/glossary/index.asp.

NRA Fact Book, 3rd ed., National Rifle Association, Washington, D.C., 1993.

Shooting Incident Analysis and Reconstruction Training Handbook, Forensic Training & Consulting, LLC, Palestine, Texas, 2013.

Terminology in Forensics: Its Use and Abuse, *Evidence Technology Magazine*, July–August 2014.

Shooting Reconstruction Myth Busters

2

Bullets and Newton's Third Law

When it comes to shooting incidents, numerous myths abound. Many of these myths have been created by the movie and television industry and are deeply ingrained in our culture. For example, who has not seen a movie in which someone was lifted off their feet, knocked off their horse, or thrown through a plate glass window by the presumed force of a bullet impact? Shooting demonstrations showing bullets striking water melons or plastic jugs filled with water leave the viewer to believe there is such an awesome power involved that, in fact, being struck by a pistol or especially a rifle bullet would surely knock a grown man down.

Nothing could be further from the truth, and Sir Isaac Newton explained it many years ago when he came up with his Third Law of Motion: To each action there is an equal and opposite reaction. In other words, if a bullet is capable of knocking a grown adult down, the adult person holding and firing that gun would be knocked down as well. Certainly, there are guns that fire bullets capable of knocking a grown man down on both ends of the gun (i.e., shooter and victim). A 120-mm howitzer immediately comes to mind. Also note that the involved persons have been described as "grown adults." If the firearm was shot by a child, certainly the child might be knocked down by the recoil of the gun upon discharge. Thus, we limit our discussion to adults firing/being hit by bullets fired from small arms (i.e., handguns and long guns).

What would it feel like to be hit in the chest by a load of 00 buckshot fired from a 12-gauge shotgun? The best answer would be found by firing a 00 buckshot round from a shouldered 12-gauge shotgun. Some of the recoil would, of course, be absorbed by the mass of the shotgun, but the impact of the shotgun butt to the shoulder would give a reasonable approximation of the impact the buckshot pellets would present.

Once again, if a child attempted to fire a high-power rifle, the recoil could certainly knock the child down. Likewise, if something outside the realm of "small arms" is fired at or by an adult, they also might be knocked down. Other than for those extremes, the typical healthy, well-nourished adult will not be knocked down, spun around, or flipped over by the impact of a bullet (or the resultant recoil of the responsible firearm) from a handgun or a long gun within the category of small arms.

This concept was clearly illustrated in a graphic video posted on the Internet several years ago, which showed a man who had been taken into custody in an officer-involved shooting and not been properly searched pull out a 9-mm pistol from his waistband and shoot himself in the left temple while left alone in an interview room by an officer. Both the recoil of the gun and the rebound of the man's head upon bullet impact were consistent with Newton's Third Law of Motion. In Figure 2.1, the man is just about to shoot himself in the left temple.

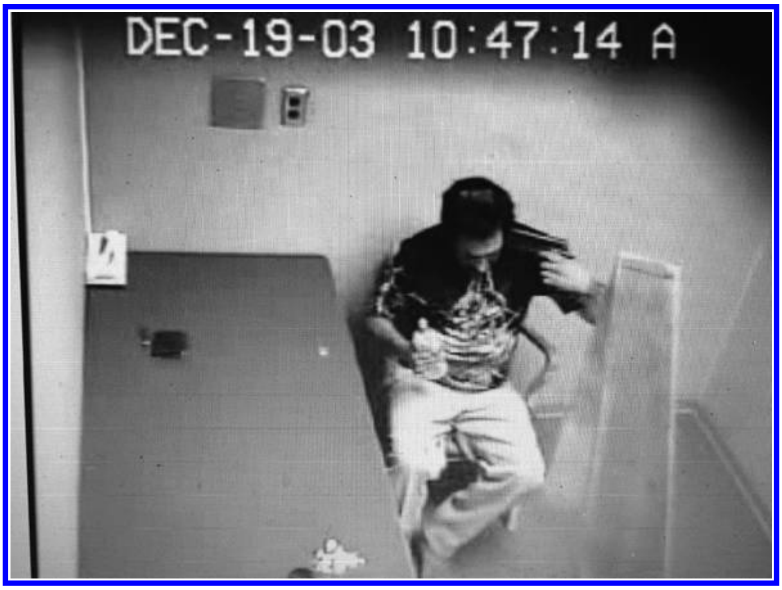


Figure 2.1 Suicide in police station.

Another video clip from the Internet from a number of years ago shows an adult male fire a bazooka and get knocked down, apparently inadequately prepared for the substantial recoil associated with large arms such as bazookas. Figure 2.2 shows the result of the bazooka discharge.

Without a doubt, the classic example of Newton's Third Law is seen in the Zapruder film of the assassination of President John F. Kennedy when viewed in slow motion before

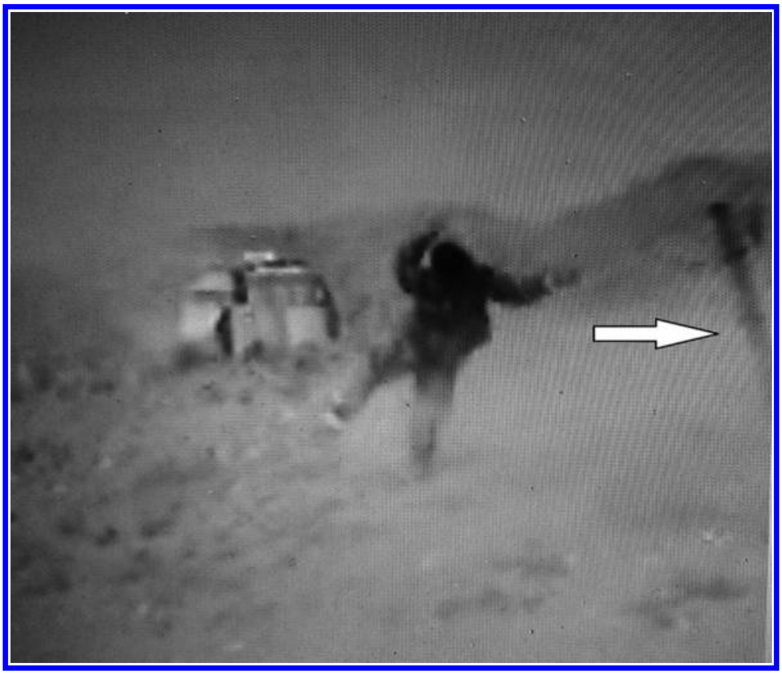


Figure 2.2 Bazooka recoil result. Arrow indicates bazooka in mid-air.

and after frame 313 (the fatal head wound). Over the many years since that fateful day in November 1963, various individuals have referred to the rearward head "snap" of President Kennedy fractions of a second after the fatal head wound as clear evidence of a shot from the front. The obvious delay, albeit minimal, between bullet impact and rearward head movement leaves no doubt that there is no association between the two.

Bullets and Intermediary Targets

In East Texas where the author resides, deer hunting takes on the significance of a cult following, superseded only by football. Because there is dense brush everywhere to contend with, deer hunters often prefer lever action 30-30 rifles, such as the Winchester model 94, because they have historically been known as "good brush guns." The reality is there is no such thing as a "good brush gun." Anything a bullet in flight strikes, including tree branches and even twigs, can destabilize the bullet and cause deflection. Figure 2.3 shows a bullet embedded in a log following deflection off a tree branch. The bullet had started to tumble and could no longer maintain its initial trajectory as evidenced by the sideways position in the log. All that having been said, I doubt I will have much luck converting the dyed-in-the-wool "brush gun fanciers" who resolutely maintain that the 30-30 round can "plough through" brush unlike other rounds.

It is quite common for individuals—including police officers, prosecutors, and defense attorneys—to presume that bullets are like laser beams, traveling undisturbed through various intermediary targets on their way to some terminal target. The use of laser beams at shooting scenes to represent trajectories probably helps perpetuate this misconception among members of the criminal justice community.

In a study conducted by the author [1], it was demonstrated that bullets passing through intermediary targets will typically show deflection, many times to a significant degree.

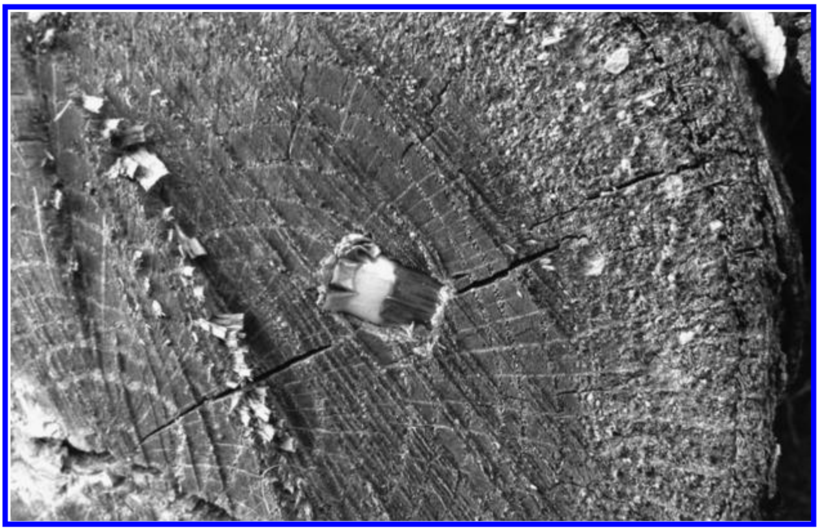


Figure 2.3 Deflected bullet in log.

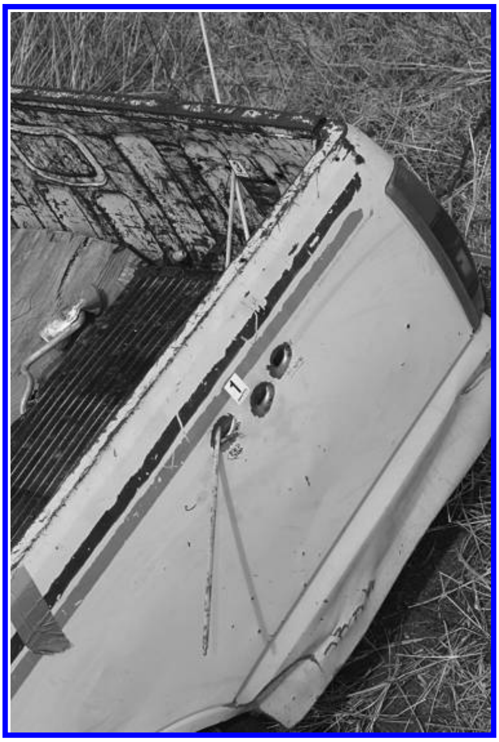


Figure 2.4 Deflection through pickup bed.

One of the targets used in the study was a pickup truck bed. Shots were fired through the single-walled side of the bed, then they passed through the double-walled tail gate. Bullet deflections are rather dramatically illustrated upon insertion of trajectory rods as shown in Figure 2.4.

The lower trajectory rod in Figure 2.4 represents the bullet path through the single-walled pickup bed. The upper trajectory rod shows the path resulting from subsequent perforations through the double-walled tailgate of the pickup. The obvious failure of the two trajectory rods to coincide is the result of multiple deflections.

This is a sometimes puzzling occurrence at shooting scenes being evaluated by inexperienced individuals who are unable to explain the failure for trajectory rods to line up when it is clear that only one bullet was responsible for the multiple holes (i.e., entry, exit, reentry, reexit situations). The training of field investigators needs to include bullet behavior upon perforation of targets. The following cases illustrate the problems relating to a lack of proper understanding of bullet behavior upon impact with various substrates.

Case 1

A police officer stated that he chased a suspect into a residence on foot. Just as the officer came through the door, the officer stated that the suspect turned back to face him with a gun in his hand pointed toward the officer. The officer said the gun had been lying on top of a counter that extended several feet from the doorway and to the officer's left. A wall was to the officer's right. The officer said that he shoved the suspect backward as he drew and

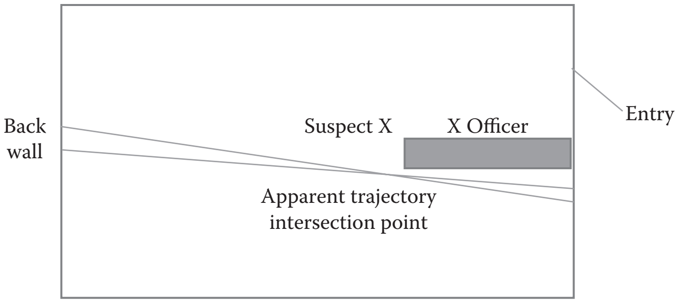


Figure 2.5 Scene of the shooting.

opened fire on the now armed suspect with his .40 caliber Glock. Two shots perforated the suspect's upper torso and passed through the wall behind him.

A lawsuit was filed by the suspect's survivors alleging wrongful use of deadly force. The plaintiff's attorney hired an expert in biomechanics to reconstruct the shooting. The expert proceeded to use the entry and exit holes in the wall to conclude that the officer's version of events was not correct. This was based on the fact that lines projected from the two fixed points (entry holes and exit holes in the wall) for each shot crossed on the opposite side of the counter from where the officer stated he shot from, indicative of the shots being fired from there, as shown in Figure 2.5.

During the trial, the state's expert provided testimony that pointed out the flawed nature of presuming that the bullets that perforated the decedent's upper torso would not have been deflected. The John F. Kennedy assassination and the "magic bullet" were referred to as a case in point. The jury ruled in favor of the defendants (the officer and his agency).

Evaluation

Expertise in one field does not translate to expertise in another field (i.e., "The cowl doth not the monk make"). That having been said, assuming that bullets do not deflect as a result of destabilization upon impact with and perforation of intermediary targets is naïve at best.

Case 2

A police officer was attempting to serve a felony warrant on a residence when it was obvious that someone was inside but not answering the door. The officer was accompanied by two fellow officers. The lead officer radioed his supervisor and obtained permission to "kick the door." Once entry was gained, the lead officer observed a female retreating to a back bedroom. The officer took a position in the bedroom doorway as his fellow officers fanned out to clear the rest of the house.

The officer at the bedroom doorway stated that the woman was seated on the bed and had a handgun in her right hand. The officer ordered her to drop the weapon twice (this was corroborated by the other two officers) before finally opening fire on her and killing her. The fatal bullet passed through her body and went into the wall behind her. Upon further examination of the scene, it was determined that the fatal bullet had nicked the corner of a satellite control box sitting on top of a television set just inside the bedroom by the doorway.

The crime scene unit from the officer's own department conducted a reconstruction of the scene. By using the defect in the satellite control box and the entry hole in the wall as reference points, the crime scene investigator concluded that the officer could not have been standing at the doorway where he said he was. Instead, the investigator would testify at trial, the officer had to be inside the bedroom because the trajectory the investigator had established was too high at the doorway (i.e., above the officer's head).

An expert testified on behalf of the officer and attempted to explain to the jury that bullets are deflected upon passing through intermediary targets and that using the initial point of impact (the control box) and the final impact site (the wall) while ignoring the intermediary target (the decedent's body) is unreliable. The crime scene investigator countered with the statement that ".45 caliber bullets are big and heavy and are not deflected under these conditions." The officer was convicted and sentenced to prison.

Evaluation

Juries must rely on individuals presented to them as experts when deciding guilt in a criminal proceeding. When given a choice between an expert for the state and an expert for the defense, studies have shown that juries tend to believe the state's expert over the defense's expert, all else being equal. This is understandable, but unfortunate in this instance. Big, heavy bullets actually have a greater propensity for ricochet than smaller bullets (e.g., .223 or .17 caliber) traveling at high velocity.

Case 3

A group of officers went to a rural cabin to arrest the occupant, a known drug dealer. As two of the officers approached the cabin in their vehicle, the suspect opened fire on them with an AR-15 rifle (.223 caliber), striking the vehicle numerous times and ultimately killing one of the officers. The crime scene investigator who arrived to reconstruct the shooting was faced with the fact that every one of the .223 bullets that struck the vehicle had fragmented and that shots had passed through multiple parts of the vehicle (i.e., door, hood, windshield, side glass).

When the case went to trial, the crime scene investigator testified that although the bullets had fragmented, "the main portion travels in a straight line." When cross-examined about the fact that the trajectory rods placed through the passenger door did not all line up appropriately with other rods in the continuing paths, the investigator testified that "that was probably due to the door moving during the shooting."

Evaluation

Bullet fragmentation is an unpredictable event, never fragmenting the same way twice. Repeated test firings during the course of research conducted by the author have shown that the larger portions as well as the smaller are deflected quite randomly. As for the explanation that the trajectory rods did not line up because of the movement of the door, it was simply a matter of multiple deflections through multiple intermediary targets (Figure 2.6).

The target shown in Figure 2.6 had been placed behind the open driver's door of the pickup before firing a .223 round through the door at an approximately 90° angle. The perforations in the cardboard target illustrate the random, unpredictable nature of bullet fragmentation.

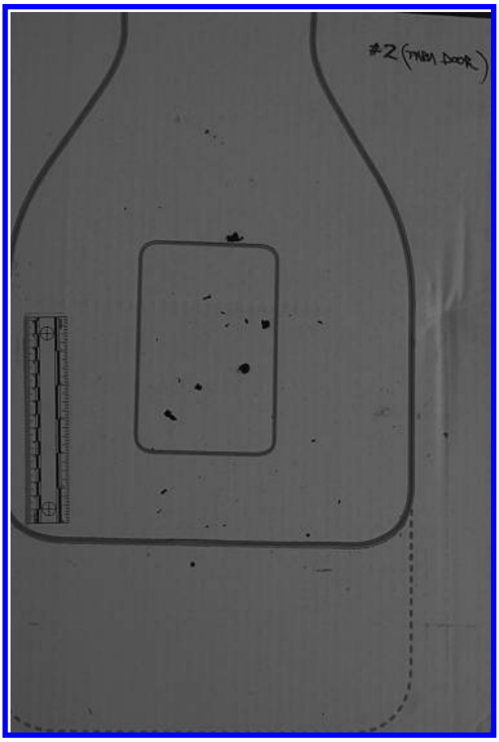


Figure 2.6 Bullet fragmentation.

Summary

Bullets encountering various intermediary targets on their way to termination can and typically do exhibit deflection. The degree of deflection is dependent on bullet design, distance from intermediary target(s) to terminal target, angle of impact, and substrate density and surface characteristics. The deflection exhibited is unpredictable and, therefore, generally nonreproducible. Chapter 9 explains how to carry out deflection studies for bullets passing through intermediary substrates. When bullet fragmentation occurs, the paths of the resultant fragments are equally unpredictable and nonreproducible.

Bullet and Shot Pellet Ricochets

Another shooting reconstruction myth has it that bullet and shot pellet ricochet marks and impressions (creases) provide no real information of value for purposes of reconstructing shooting incidents. Nothing could be further from the truth. It is certainly a fact that ricochets are pretty much unpredictable as far as predicting exactly where a ricocheting bullet or pellet might land. On the other hand, bullet/shot pellet ricochet marks and creases can provide a lot of useful information under the right circumstances (see Chapter 10).

Ricochet marks are the result of bullet/pellet deflection off surfaces resulting in a mark without any perceptible depth. Ricochet marks (Figure 2.7) can provide information as to the direction of travel of the projectile, the general rifling characteristics of the barrel

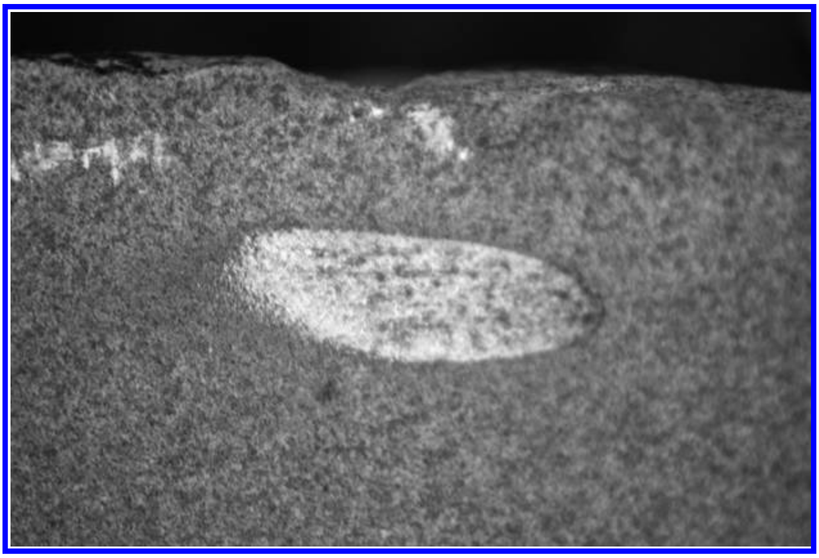


Figure 2.7 Ricochet mark on stone.

(assuming a rifled barrel was involved), and provide information as to bullet construction (e.g., lead versus copper jacketed).

Ricochet creases (Figure 2.8) are the result of bullet/pellet deflection off surfaces resulting in a depression having perceptible depth. In addition to the information listed in the previous paragraph for ricochet creases, the angles of impact and ricochet may be approximated in some instances.

The techniques for carrying out these analyses for ricochet marks and creases are explained in detail in Chapter 10. Thus, an investigator needs to be aware of the utility of ricochet marks and creases lest valuable information be overlooked.

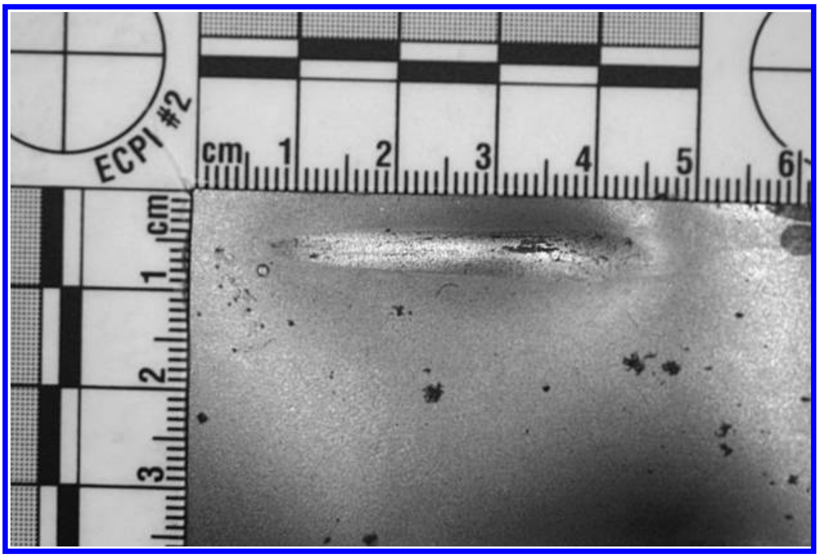


Figure 2.8 Ricochet crease in steel.

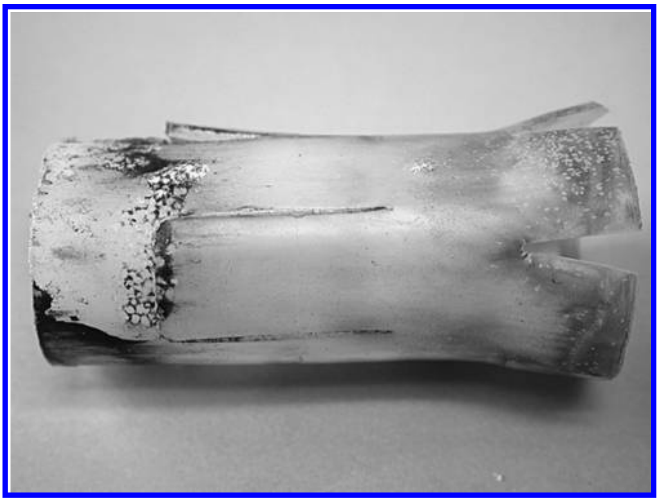


Figure 2.9 Fired shot cup.

Shotgun Wads, Cups, and Wrappers

When a shotgun shell is discharged, components that separate the shot pellets from the powder charge and/or insulate the barrel bore from the pellets (i.e., wads, cups, and wrappers) are typically projected downrange along with the pellets. These items, when located by unaware investigators, are frequently ignored owing to their perceived lack of value. Once again, this myth needs to be dispelled. Not only do those components have potential value with regard to helping approximate shooter position (they can only travel so far before gravity and air friction take them to ground), but they also provide information as to brand, gauge, and load (i.e., pellet size). This will be discussed in detail in Chapter 6. Figure 2.9 shows a fired shotgun cup.

Gunshot Residues

The myth that has arisen concerning gunshot residues (GSR) is that the testing for these residues has been shown to be unpredictable, ineffective, and, therefore, pretty much a waste of time. As explained in detail in Chapter 8, it is the misapplication of GSR testing that is responsible for the bad reputation that has come to GSR testing. Part of the confusion, as has been already addressed in Chapter 1, has to do with the lack of understanding of exactly what is meant by the term "GSR." To reiterate, there are two forms of gunshot residue: primer residue comes from the combustion (actually an explosion) of the priming mixture of a cartridge or shotgun shell, whereas gunpowder residue comes from the combustion of gun powder. These two decidedly different residues are used for two decidedly different forensic purposes, as also already discussed.

As the author has frequently mentioned in the context of shooting incident reconstruction courses, "There is a time and place for GSR (both powder and primer residues) testing but it is not every time and every place." The policies relating to collection and testing of gunshot primer residues for police agencies across the United States range from collecting and testing the samples in every shooting case, to not collecting them at all. In the author's opinion, not collecting samples at all is the equivalent of "throwing the baby out with the bath water." As already stated, the other extreme (i.e., collecting/testing in every case) is ill advised as well.

So, when is the "right time" for collecting/testing samples of suspected gunshot primer residues? The answer must be directed at what are really two related questions: (1) When to collect? (2) When to test? Obviously, if samples are not collected, there will be nothing to test. Thus, the best answer to the first question is to collect whenever there appears to be any potential probative value. The unfortunate reality is that one seldom knows for sure when there is potential probative value as information regarding shootings is subject to change during the course of investigation. Thus, we are back to the policy of collecting samples in every case.

As for the question of when to test the samples that have been collected, the answer is typically more obvious. Accordingly, storing collected samples and not having them tested until it becomes clear that they are potentially of probative value is, in the author's opinion, the most realistic policy. The following case examples provide insight into the issue.

Case 1

An individual was shot from close range with a .40 caliber handgun in the mid-chest area, receiving a fatal wound. The crime scene investigator arrived and took samples from the deceased's hands and secured the samples for transfer to the property/evidence unit for possible future testing for primer residues.

Evaluation

Because the individual sampled was the victim of a gunshot wound, taking samples was entirely inappropriate. It is expected that positive results would be found. What if the samples collected were tested for gunshot primer residues and none were found? There are a variety of explanations to account for negative findings (e.g., improper protection of the hands before sampling, improper sampling technique, improper analytical technique, and improper instrument calibration).

It is this very type of testing and the lack of getting "predicted" results that has, in large part, been responsible for the bad rap that has been given to gunshot primer residue testing in general.

Case 2

A 911 call was received at a local police agency from a resident claiming that he had returned home and found his roommate dead of an apparent gunshot. Upon arrival of first responders, the reporting person stated that he did not enter the room or touch anything inside before the police arrived. He further stated, in response to questions from the investigator who arrived soon after, that he had not handled or fired any firearms or been around any firearms being discharged recently. The investigator asked if the man would allow samples to be collected from his hands. The man agreed and the samples were later tested with positive results for gunshot primer residues. Ultimately, the man confessed to having shot his roommate when confronted with the test results.

Evaluation

This case exemplifies the circumstances that are entirely appropriate for gunshot residue testing: No apparent reason for the reporting person to have gunshot primer residues on his person. As a side point, some agencies have now, appropriately, started sampling facial hair (including nasal) as well as the face itself.

Case 3

A woman was found lying on her bedroom floor dead of a gunshot wound to her chest. A handgun was lying on the floor nearby. When detectives arrived, the lead detective told the crime scene investigators to "Be sure to sample her hands so that we can determine if this is a homicide or a suicide."

Evaluation

As with case 1, it is inappropriate to sample/test the victim of a gunshot. The myth that has prevailed over the years is that "if there is more residue on the palms than the backs of the hands that points to homicide rather than suicide." This is simply wrong for a couple of reasons: There is no standardized sampling, making it impossible to attach any real quantitative value to test results. Handling the gun could easily result in more residue being on the palms as opposed to the backs of the hands.

Case 4

A suspect is arrested in a sniper shooting from some 600 yards away from the victim. The suspect was found to be in possession of a Remington model 700 bolt action 30-06 rifle. He was brought to the local crime laboratory where a criminalist collected samples from his hands. When tested, the samples were found to contain gunshot primer residues.

Evaluation

Another myth has it that rifles, particularly bolt action rifles that have been fired only once during a shooting incident, are unlikely to deposit primer residues. The message is one we have all heard before—"Never assume anything!"

Cartridge Case Ejection

The myth associated with ejected cartridge cases is that no useful information concerning shooter position can be derived from the location of fired cartridge cases. Although that is certainly the case under certain circumstances, it is not always so. The investigator should evaluate each incident carefully before deciding that no useful information exists regarding shooter position. Chapter 5 gives an in-depth look at this subject.

To be able to relate fired cartridge case locations with shooter position(s) the following needs to be evaluated:

1. Weapon ejection characteristics
2. Direction of fire
3. Are there a representative number of ejected fired cartridge cases
4. Height firearm was fired from
5. Orientation of the firearm (vertically and horizontally)
6. Terrain the cartridge cases landed on

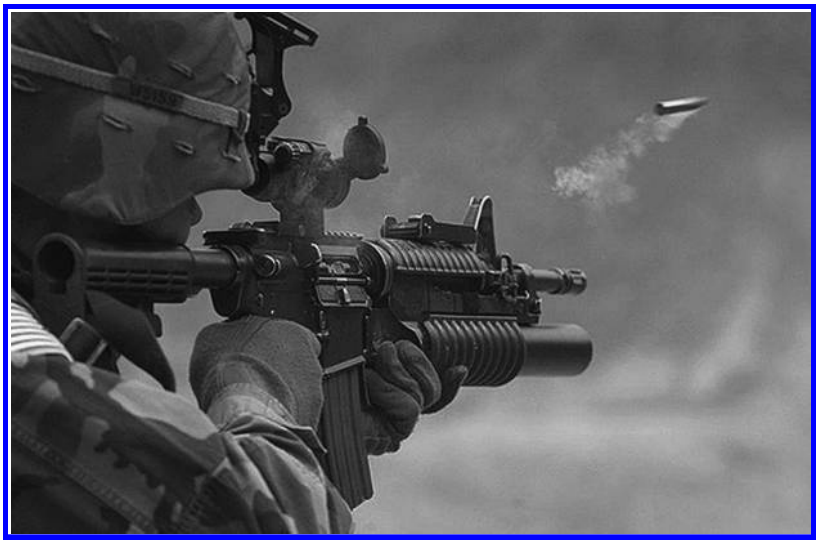


Figure 2.10 Ejected cartridge cases.

7. Grip the firearm was being held with
8. Type of round that was fired

Typical cartridge case ejection from a shoulder weapon is illustrated in Figure 2.10.

Obviously, a number of the listed criteria can be difficult or impossible to ascertain. However, under certain circumstances, it may be possible to arrive at a meaningful conclusion as to where the shooter was positioned. The following cases serve to illustrate.

Case 1

An officer on foot approaches a vehicle parked backed in on a flat, grassy area between two buildings. The officer stated that as he got within about 4 feet of the driver's side window the vehicle started up, turned toward him, and accelerated forward causing him to flee. Once out of the path of the vehicle, the officer stated that he fired from a "standard tactical position" toward the then fleeing vehicle. Five fired cartridge cases were found clustered together on the grass. The scene investigator photographed the cartridge cases and collected them with no further documentation.

Evaluation

In this incident, the investigator could ascertain the direction of fire to a reasonable degree of certainty. He could also have been relatively confident that the positions of the fired cartridge cases on the flat, grassy area were fairly representative of their initial points of impact. Additionally, the involved officer could have provided some relatively accurate information as to the height, position, orientation, and grip of his service pistol during the shooting. Finally, the fact that five fired cartridge cases were present lent credibility to the representative nature of their location relative to the ejection characteristics of the pistol.

The locations of the fired cartridge cases should have been documented through use of a baseline measuring technique and test firing of the weapon using similar ammunition on similar terrain with the involved officer doing the firing (ideally) should have been done in order to establish the probable position(s) of the officer during the firing of the five shots.

Case 2

A shooting takes place inside a high school classroom in which a deranged student fired six times with an H&K 9-mm semiautomatic pistol, killing the teacher and severely injuring four students before taking his own life by shooting himself in the right temple. Cartridge cases are found scattered about in the classroom that held 30 individual student desks in five rows of six desks. The crime scene investigator documented the fired cartridge case locations both photographically and using three-dimensional imaging but nothing further as far as the fired cartridge cases were concerned.

Evaluation

Owing to the presence of the desks, the movement of individuals during the incident and afterward, and the smooth tile surface of the floor, there would be no reliability concerning cartridge case locations and shooter positions. What was done by the crime scene investigator was appropriate under the conditions of the scene.

Blood Back Spatter from Gunshots

The myth associated with blood back spatter (Figure 2.11) is that it is a reliable way to distinguish homicide from suicide in shooting incidents. As with several of the myths already discussed, the myth is based on partial truth. Under some circumstances, the presence of back spatter does present strong evidence of suicide, for example, when present on the back of the right hand of an individual with a contact gunshot wound to the right temple accompanied by corresponding spatter on the handgun involved.

In a study published in 2002 by Karger et al. in the *Journal of Forensic Medicine and Pathology*, it was shown that back spatter was found on the hands in only 35% of the

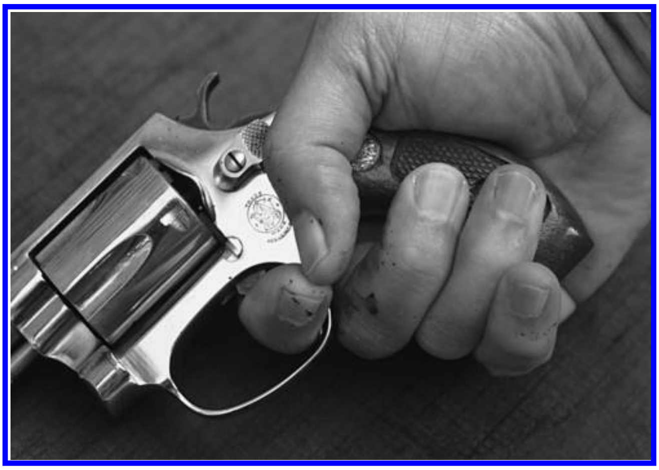


Figure 2.11 Back spatter on hand.

confirmed suicide cases studies. Thus, not finding blood on the hands cannot be the basis for arriving at any meaningful conclusion.

Exercises

1. A scene investigator attempting to use trajectory rods to illustrate the path of a bullet through the front passenger door of a vehicle, the front passenger seat back, and the fold down armrest of the driver's seat finds that the three trajectory rods placed through the various intermediary targets fail to line up (i.e., she cannot connect the rods without there being a curvature). What should she do?

   Answer: The failure of the rods to line up is simply a consequence of bullet deflection as each intermediary target is encountered. The correct procedure is to let each rod be positioned as the entry and exit holes dictate, then photograph, sketch, and obtain linear and angular coordinates for each. An explanation for the failure of the rods to line up should go into the investigator's notes and any report issued.
2. A prosecutor is holding a pretrial conference with a detective concerning the fact that the decedent in the case being discussed was shot in the chest with a .357 Magnum round at close range by his girlfriend (the defendant). The prosecutor is asking the detective to explain why the 6-foot-tall, 225-pound man would not have been knocked backward upon bullet impact. How should the detective respond?

   Answer: The detective should point out that it is a simple matter of physics and Newton's Third Law of Motion—To each action, there is an equal and opposite reaction. Thus, if the decedent had been knocked backward by the bullet, the shooter would have likely been knocked backward as well, especially as the defendant is 5 feet 4 inches tall and weighs about 120 pounds.
3. The scene investigator and the lead detective are having a discussion concerning the usefulness of the location of a single fired cartridge case, found on the street near the curb, for determining the shooter's location when the shot was fired. The scene investigator states that there is not enough information available, there is only one fired cartridge case, and the street surface makes the final resting spot of the cartridge case an unreliable indicator. The detective disagrees and says he thinks shooter location is going to be important, and it is possible to use the location of the fired cartridge case to predict it. Who is right?

   Answer: The scene investigator is right. To begin with, a single fired cartridge case does not provide sufficient basis for any shooter location prediction under the best circumstance. The reason being that from time to time firearms produce atypical ejections and with only one fired cartridge case, there is no way to know for sure that an atypical (anomalous) ejection did not occur.
4. An elderly man is found seated in a recliner chair in his living room dead of a large wound to his chest. He has a sawed-off shotgun in his lap. No back spatter of blood is visible on either hand. There is a DNR (do not resuscitate) note written on a pad next to the chair and apparently signed by the man. The investigator believes it is a staged suicide (i.e., actually a homicide). What do you say?

   Answer: The lack of back spatter of blood on the hands is insufficient, in and of itself, to conclude homicide. Studies show that it is more likely that back spatter will not show up in suicides for a variety of reasons. As the man was fully clothed, that may account for the lack of back spatter on the hands. In any event, the investigator will need to have the firearm taken to the DNA laboratory and be tested to see whose DNA might be present on it and the discharged shot shell. Also, he should have the handwriting on the DNR note examined by a questioned document expert as well as do a complete investigation as to any possible motives for suicide (e.g., poor health, financial loss).

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Theory and Practice of Shooting Reconstruction

3

Shooting Reconstruction and the Scientific Method

The analysis and reconstruction of shooting incidents is based on the application of the scientific method. Although it is certainly advantageous to have been educated in the sciences, the nonscientist can certainly learn the fundamentals of the scientific method and use them as required in making inquiries into the events associated with a shooting incident. Because the scientific method is nothing more than a logical thought process, many nonscientists regularly use the scientific method without realizing it.

For example, suppose that you get in your car to go to work and, upon inserting the key into the ignition and attempting to start the engine, there is no response. If you have any basic knowledge of automotive electrical systems you would probably reason that either you have a dead battery or there is something wrong with the electrical system such as a starting module gone bad. At that point, most of us would try the lights, horn, or radio to determine whether the battery is the culprit. If those tests yield positive results (i.e., the lights, horn, and radio all work), then we would conclude that the battery was not the problem. At this point, most of us would throw in the towel and call for a wrecker to come get the car and transport it to the dealership so that an expert can complete the job.

That example is an appropriate analogy of shooting incident analysis and reconstruction. A logical, methodical inquiry is made as to the various aspects of an incident under investigation. There are a number of inquiries that we can make ourselves in the field. At some point, we are likely to need the assistance of experts in the crime laboratory. The more one understands about firearms and ammunition components, the more one can independently evaluate their significance at a shooting scene. A person with only a limited knowledge of these items is at a decided disadvantage, but all is not lost. Reading, studying, experimenting, watching, and listening can, over time, provide the necessary basics to be able to function effectively in the analysis and reconstruction of shooting incidents.

There is no mistaking it—someone with an academic degree in the sciences (the more chemistry and physics, the better) and a solid understanding of the function and operation of a wide variety of firearms is in much better shape to learn how to approach the reconstruction of a shooting incident than someone at the other end of the spectrum (i.e., little or no science background and little or no familiarity with firearms and ammunition). But, again, anyone willing to devote the required time and energy can reach the necessary level of understanding of the subject. As the saying goes, “We are all ignorant, just on different subjects.” Ignorance is waiting to be overcome by education.

Equally important, qualifications for becoming effective in the analysis and reconstruction of shooting incidents are being detail oriented and being goal oriented. For want of a better definition, there is a highly desirable attitude that anyone involved in the documentation, preservation, and collection of physical evidence should have. I have referred to it previously in this text: having a "reconstruction mentality." In today's criminal justice organizational structure, it is rare that one individual will have the sole responsibility for all the aspects involved in the reconstruction of shooting incidents. However, unless each involved investigator constantly has their focus on the "big picture," the fruits of their labor can be quite disjointed.

Having a reconstruction mentality allows each investigator to better evaluate what needs to be collected at a shooting scene and to recognize what does not appear to be present and needs to be searched for. Without giving thought to the possible interrelationships of physical evidence and how it might all dovetail together, one can be reduced to being simply a "forensic garbage collector."

Defining the Problem

A big step toward establishing and maintaining a reconstruction mentality is to understand and regularly apply the scientific method. The scientific method begins with defining the problem or question at hand. There are typically two tiers of problems. The top tier in a shooting incident reconstruction is typically "Who shot who from where?" Below that are the myriad of questions such as "Whose blood is this?" or "Is this the gun that fired the fatal shot?"—all for which the scientific method will be applied.

Making Observations

Once the problem or question at hand has been defined, the next step is to make observations that appear to be pertinent. Using the two questions posed in the above paragraph, we might look to see if it appears that there is only one blood source. Whether we can discern the potential number of donors of blood at a particular scene, we look to see if any of the individual bloodstains appear to be out of context with the main pattern being evaluated. Bloodstains that appear out of context should be the primary focus of a scene investigation.

As for the question regarding the gun that might have fired the fatal shot, we can begin by observing the gun for caliber, followed by looking at the entry wound and any fired cartridge cases present. Suppose the gun is a 9-mm caliber and a .45-caliber–fired cartridge case is lying on the floor near the body. This is where the scene investigator with a reconstruction mentality recognizes that the 9-mm pistol could not have fired the .45-caliber cartridge case. Let us next suppose that the entry wound is such that it appears to be more consistent with a .45-caliber bullet than a 9-mm bullet. At this point, the investigator recognizes that another gun is likely responsible. A search for another gun is clearly in order. An individual who is not nearly as astute (i.e., a "forensic garbage collector") merely collects what is there and leaves it for someone else to sort it all out.

Formulate a Theory

Based on our observations, we can usually come up with a theory. Continuing with the hypothetical firearm, let us suppose that the investigator locates a .45-caliber semiautomatic pistol under a sofa in the room where the victim's body was found. Let us further suppose that the pistol has the hammer back (i.e., it is cocked), and there is a live round in the chamber and several more in the magazine. The theory that fits all this is that this is likely the gun that fired the fatal shot.

Test the Theory

Once a theory has been formulated, it should be tested. In the example of the .45-caliber pistol, the crime laboratory firearms unit will be called upon to carry out the testing required. The pistol will first need to be function tested. Once it is determined to be operable, the pistol will be test fired (usually a minimum of three rounds are fired and the bullets and cartridge cases collected). The evidence cartridge case in this example, along with a bullet presumably recovered at autopsy, will then be compared to the test bullets and test cartridge cases.

Modify the Theory as Required

If testing shows anything contrary to our proposed theory, the theory must be modified accordingly. For example, suppose in our ongoing .45-caliber pistol scenario the laboratory results indicate that the bullet recovered at autopsy and the cartridge case found at the scene, although both .45 caliber, were not fired in the pistol found at the scene. Obviously, our theory now must be modified to state that a .45-caliber firearm is responsible but not the one found at the scene.

This is how the scientific method works and how it should be applied to each and every piece of physical evidence at a shooting scene. The unfortunate reality, as anyone recognizes who has worked for an agency in a high demand (i.e., high crime) service area, is time constraints. There is a constant struggle in trying to balance proper investigative efforts with available time. Admittedly, we cannot always have the luxury of enough time to do everything we know how to do or need to do at a scene. We must simply strive to be judicious with our available time and get the most out of it.

On-Scene Evidence Evaluation/Documentation

Clearly, the most important aspect of the analysis and reconstruction of a shooting incident is the initial on-scene evidence evaluation and documentation. For most of the potential evidence in shooting incidents, if it is not appropriately dealt with during the initial investigation, chances are very slim that it can be taken care of properly through photographs and/or sketches alone. Before an investigator enters a scene, the following needs to be verified:

1. The scene has been made safe to enter.
2. Scene security has been established.
3. A point of ingress/egress has been determined.
4. Warrant considerations have been addressed.
5. A crime scene entry log has been initiated.
6. Appropriate scene entry gear is available (gloves, face masks, head coverings disposable coveralls, and shoe covers).

7. Necessary equipment is available (e.g., camera equipment, metal detector, trajectory equipment).
8. Adequate personnel are present (e.g., photographer, latent print examiner, blood spatter expert, death investigator).

The protocol for the evidence evaluation and documentation of shooting incidents is the same as for any other type of criminal investigation. The following outline is pretty much standard for police agencies across the United States. If followed to the letter, the ability to recover admissible evidence and to be able to reconstruct the involved events is greatly enhanced.

1. Set up a staging area outside the scene perimeter.
2. Conduct a walkthrough of the scene (usually done by the first responding officer and the crime scene investigation team leader).
3. Note visible evidence, paying particular attention to any transitory evidence that must be dealt with immediately or risk loss/contamination.
4. Exit the scene and return to the staging area.
5. Call for any additional equipment/expertise determined to be lacking.
6. Develop an action plan with team members before reentering the scene.
7. Initiate the action plan (typically beginning with addressing any transitory evidence issues).

Note: Included in the category of transitory evidence is trace evidence (hairs, fibers, blood, tissue, etc.) adhering to the margins of bullet holes that might be compromised by the insertion of trajectory rods.

8. Documentation should include photographs, written notes, and rough sketches that include measurements.
9. Photographs should be taken of the entire scene following the basic rule "general to specific."
10. Photographs should be taken that do not reflect any scene alteration (i.e., no inserted evidence markers, arrows, measuring devices).
11. Once the "as is" photographs have been completed, the typical crime scene markers are added and the photographs taken with the markers, measuring devices, etc., within the field of view.
12. All bullet impact sites/entries/exits need to have their dimensional components determined (i.e., x, y linear coordinates that fix positions).
13. Assuming all potential trace evidence associated with bullet impact sites/entries/exits has been appropriately dealt with, trajectory rods are inserted as is appropriate (see the discussion in Chapter 6 on trajectory rods and their placement for more information).
14. A minimum of two photographs must be taken of each trajectory rod in place, the x angular image and the y angular image (see the following discussion on trajectory rods and their placement for more information).
15. Evidence collection may now begin, being sure to complete an evidence collection log.
16. Once all evidence appears to have been collected, a review of the collected evidence is conducted and a final walkthrough of the scene is done to help ensure

nothing of interest was overlooked (shot accounting should be done at this point as well as ensuring that appropriate control standards were collected).

17. The scene may now be released.

The overriding factor, as already discussed, is that each team member has a reconstruction mentality throughout the scene processing. Then and only then is there likely to have been sufficient thought and effort exerted. The basic rule to crime scene investigation in general is you get out of it pretty much what you put into it. Thus, a mediocre effort is appropriately rewarded with mediocre results and superior effort generally produces superior results.

Off-Scene Evaluation and Documentation

Depending on the particular circumstances of a shooting incident, a substantial amount of off-scene evaluation and documentation may be required. Things such as establishing the source of the involved firearm, determining the possible motive for the shooting, establishing the level of firearms familiarity of the alleged shooter, and neighborhood canvassing are typically involved. The following case illustrates some of the considerations for investigators:

Case synopsis—A woman calls 911 to report that her sister had just shot herself at the apartment where the sister and her boyfriend resided. The woman stated that she had stopped by to visit and upon knocking on the door, her sister's boyfriend opened the door and told her that her sister had just shot herself and he asked her to call 911 while he went back into the bedroom to tend to the injured sister.

The first officer to respond arrives within approximately 30 minutes. He finds the body of the sister lying inside the master bedroom closet on her right side, with no pulse and cold to the touch, with a penetrating gunshot wound to the back of the head just behind the right ear. He notes that, on his arrival, the boyfriend was dressed in shorts but did not have on a shirt or shoes. The boyfriend's hair appeared damp, as if recently washed. The officer notes there appears to be postmortem lividity on the buttocks of the body. He further notes that bloodstains on the body and a nearby clothes hamper appear to be dry. When detectives arrive approximately 1 hour later, he relates all this to them.

During their interview of the boyfriend, detectives learn that he and the dead girl had been having an argument that had started the previous night (it is now nearly 3:00 p.m. the next day) over his having told her "he needed more space" and wished her to move out. He further stated that he spent the night on the couch and she slept alone in the bed that night. Upon awakening, he stated that she reinitiated the argument. He related that his reaction was to get his handgun and a box of ammunition and drive to an area where he could target shoot. He said he spent about 2 hours target shooting before coming back to the apartment.

When he went inside, he said he got his cleaning kit out, sat on the end of the bed and had just finished cleaning and reloading the gun, a Hawes single action .44 magnum revolver, when she walked in, grabbed the gun out of his hand, and stepped into the closet while facing outward at him and put the gun to her head and said "Maybe this will make you happy." He said he lunged toward her in an effort to grab the gun but, as he did so, it discharged. He said she fell forward into the closet landing on her right side just before her sister arrived and knocked on the door.

The sister was also interviewed by investigators while still at the scene and related that she had planned to stop by and visit her sister and take her shopping. She told detectives that she knew nothing about any problems between her sister and the boyfriend and had not heard anything that sounded like a gunshot when she drove up to the apartment and went to the front door and knocked.

Off-scene issues—There are a number of off-scene issues that need to be addressed in the analysis and reconstruction effort that follows the interviews of the two individuals at the scene.

1. What role, if any, did the dead girl's sister play in the shooting?

   The key to answering this might simply rest with determining when the sister actually arrived at the apartment. Possible means to establish that are listed below:
   a. Go out to the sister's car and touch the hood to determine if the engine is warm.
   b. Check surveillance cameras at the apartment building.
   c. Canvass the building to find out if anyone saw her arrive.
2. Is the boyfriend's statement factual concerning his going target shooting, returning, and cleaning and reloading the gun?
   a. Go out to his car and touch the hood to determine if the engine is warm.
   b. Check surveillance cameras at the apartment building.
   c. Canvass the building to find out if anyone saw him leave/arrive.
   d. Have him take you to the target shooting location.
   e. Where is the fired brass from the target shooting?
   f. Where is the cleaning kit? Does it reflect recent use?
   g. Where is the ammunition box he reloaded from?
   h. Where are the clothes/footwear that he wore to go target shooting?
3. Could the girl have physically carried out shooting herself in the back of the head?
   a. What was her level of familiarity with single action revolvers in general?
   b. What was her level of familiarity with the revolver in this incident?
   c. What was the trajectory of the bullet in her head?
   d. Determine her arm's length and conduct a reenactment with the revolver.

How might gunshot residue play a role in the analysis and reconstruction of this shooting?

1. Gunshot primer residue—Finding or not finding gunshot primer residue on the dead girl is irrelevant because she is the victim of a shooting. Finding or not finding gunshot primer residue on him is irrelevant in this instance because he has stated he fired and handled the gun before the shooting, and he claimed he lunged toward the victim just as the shot was fired.
2. Gun powder residue—The margins of the entry wound in the girl's head should be examined for evidence of gunpowder particles and/or soot deposits.

As it turned out, she had a thick layer of hair over the site of the entry wound, a circular area of which had been burned away by the muzzle blast and a dark soot deposit was left. This was a clear evidence of a close-range shot with the muzzle of the gun just above the point of entry but not pressed hard against it.

The boyfriend was ultimately charged with murder, convicted, and sentenced to 10 years in prison. No investigation of the surviving sister was ever done, and most of the listed

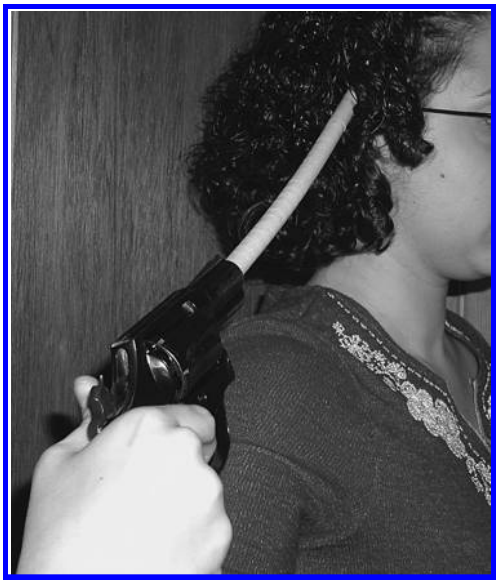

Figure 3.1 Suicide reenactment.

off-scene investigative efforts were not carried out. One could argue that justice was done, but was it really?

A preliminary weapon position reconstruction is illustrated in Figure 3.1.

Goal of Shooting Reconstruction

Shooting incident analysis and reconstruction involves many different processes having varying levels of complexity. Shooting incidents can range from fairly simple events, such as a single weapon used to fire a single shot, to very complex situations involving multiple weapons used to fire multiple shots. A wide array of mitigating circumstances may further add to the complexity of the incident.

Regardless of the complexity, the same basic principles are used in the reconstruction of the events leading up to, during, and after a shooting. A careful, logical approach aids in ensuring thorough examination. It may also make what may first appear to be a nearly overwhelming situation a bit more manageable.

Shooting incident analysis and reconstruction is based on the application of a number of disciplines, some of which are firearms related and some of which are not. The firearms-related disciplines include ballistics (primarily external and terminal), firearms identification, and wound ballistics. Other disciplines that are often utilized in shooting reconstructions include blood spatter interpretation, trace evidence, DNA, footwear and tire tread examination, and latent prints.

Reconstructions take into account all the available documentation (reports, affidavits, photos, videos, sketches, notes, etc.), physical evidence, and witness accounts. In order to develop a likely scenario that best fits all this information, it is critical that, if possible, nothing be left without explanation. Sometimes, however, there are unexplainable things at scenes. When this occurs, it is important to recognize it and not attempt to alter the evidence in an attempt to make everything fit.

Thus, the goal of shooting reconstruction is to formulate a probable or likely sequence of events based on the physical evidence and related documentation. To attempt to do more is foolhardy and cannot be justified under any circumstance. On the other hand, this is not to be taken as an admonition to be noncommittal, merely to ensure that all opinions are grounded in good science.

Limitations of Shooting Reconstructions

It must be remembered that a shooting reconstruction is nothing more than a reasonable explanation rather than a proposal of absolute fact. There is typically no way that the shooting reconstructionist will be able to determine with 100% certainty each and every detail associated with a shooting. There are simply too many variables. For example, the simple question as to how a shooter's feet or hands may have been positioned at some point during a shooting may be approximated. It is unlikely that their exact positions may be determined except in rare situations.

Admittedly, everyone associated with the product of a shooting incident reconstruction effort prefers definitive statements that leave no room for alternative explanations. Unfortunately, the norm is to use words such as probable or likely when assessing potential activities relating to a shooting incident. Doing so, of course, opens the door to questions such as "How probable?" or "How likely?" The last thing that anyone should attempt to do is provide a numerical answer to those questions (e.g., 90%, 51%). The best answer to those questions is to simply say, "More likely than not, but I have no way of putting a number to it."

Once an expert responds to a probability question with a quantitative answer, they can expect an ongoing series of questions regarding the probability of each and every aspect of the reconstruction. If an expert can be proven wrong about any aspect of a reconstruction, whether or not dealing with probabilities, the entire theory of their reconstruction will come under assault. The standard line of cross examination, whether by the prosecution or the defense, will then be to repeatedly ask "You made a mistake on that didn't you?" followed by "How do we know that you did not make other mistakes in your reconstruction?" There are no good responses to that last question.

Reenactment in Shooting Reconstructions

Many times, questions arise that can best be answered through some form of reenactment. There are a variety of ways that a reenactment may be accomplished:

1. Full scale with live actors
2. Full scale with mannequins
3. Full scale with a combination of live actors and mannequins
4. Full scale without mannequins/actors
5. Scale models
6. Computer animations

Regardless of which methodology is selected, a number of things need to be accurately determined concerning individuals who are to be represented including:

1. Height
2. Weight
3. Body shape/build
4. Hair length/color/style
5. Clothing style/color and footwear worn during incident
6. Type eye glasses (if worn)
7. Dominant hand

Full-Scale Reenactments

If any of the full scale options are to be used, it must be determined whether the original scene is to be used (and the reenactment documented photographically, either with or without video) or all or part of the scene is to be reconstructed in the courtroom and the reenactment carried out in front of the jury. Obviously, a compromise must be reached between ease of presentation and effectiveness of presentation. Some examples are shown in Figures 3.2 through 3.4.

Some of the possibilities for full-scale scene presentations that have been set up in a courtroom include the following:

- Using masking tape to lay out the location of walls on the courtroom floor
- Using cardboard in the courtroom to represent walls at a scene
- Using a door frame and door from the scene and setting it up in the courtroom

When a parking lot or a large room has been available within the confines of the courthouse, the following full-scale presentations have been used:

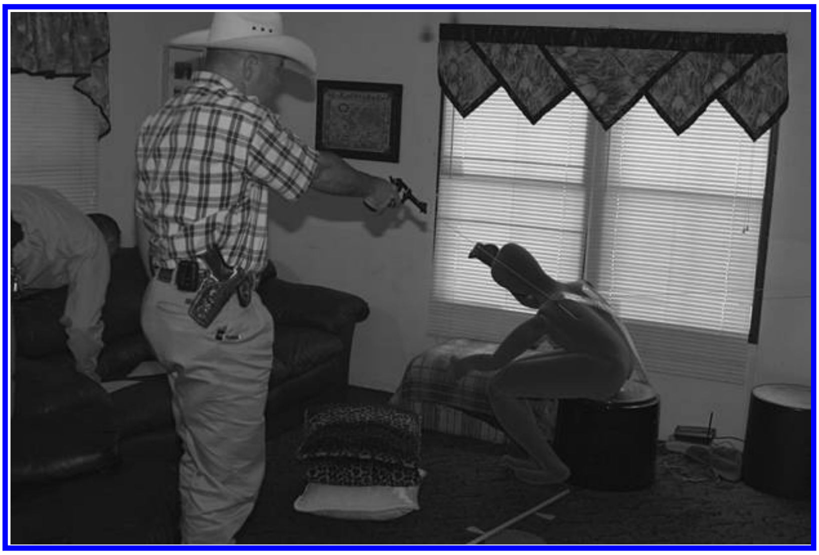

Figure 3.2 Reconstruction of a shooting.

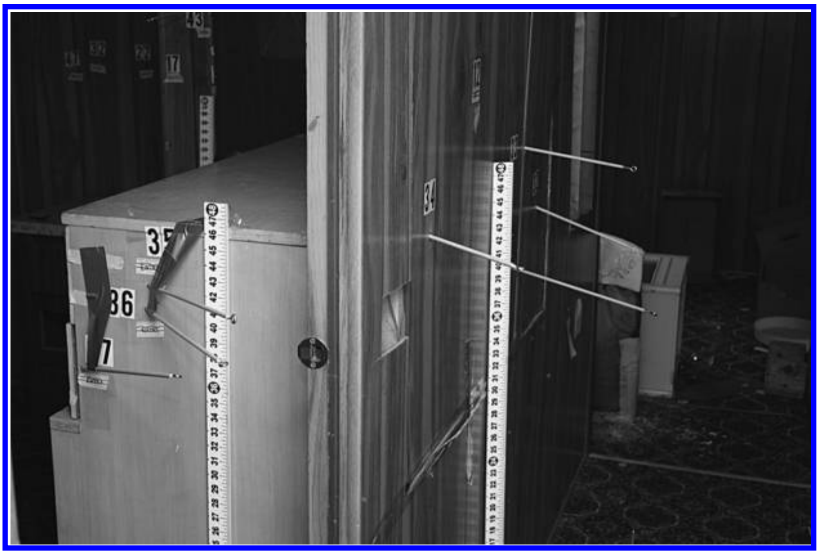

Figure 3.3 Full-scale indoor reconstruction.

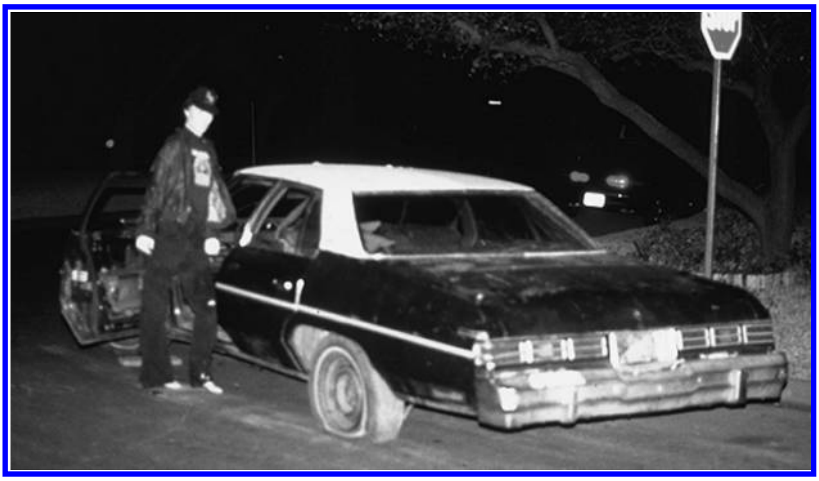

Figure 3.4 Outdoor reenactment.

- Using the actual vehicle involved in a shooting
- Using a portion of a vehicle (front cockpit area was cut out and placed on casters)

When feasible, which is not often, the jury has been transported to the actual scene for a full-scale reenactment. Obviously, logistical, safety, and legal considerations abound when taking this approach.

The "Mother of All Full-Scale Reenactments" is the combined efforts associated with the analysis and reconstruction of the November 22, 1963, assassination of President John F. Kennedy at Dealey Plaza in Dallas, Texas. A re-creation of the shooting is illustrated in Figure 3.5.

The actual scene was used to conduct several reenactments over the ensuing years. A re-creation of the "nest" that Lee Harvey Oswald is believed to have been firing from on the sixth floor of the Texas School Book Depository is shown in Figure 3.6.

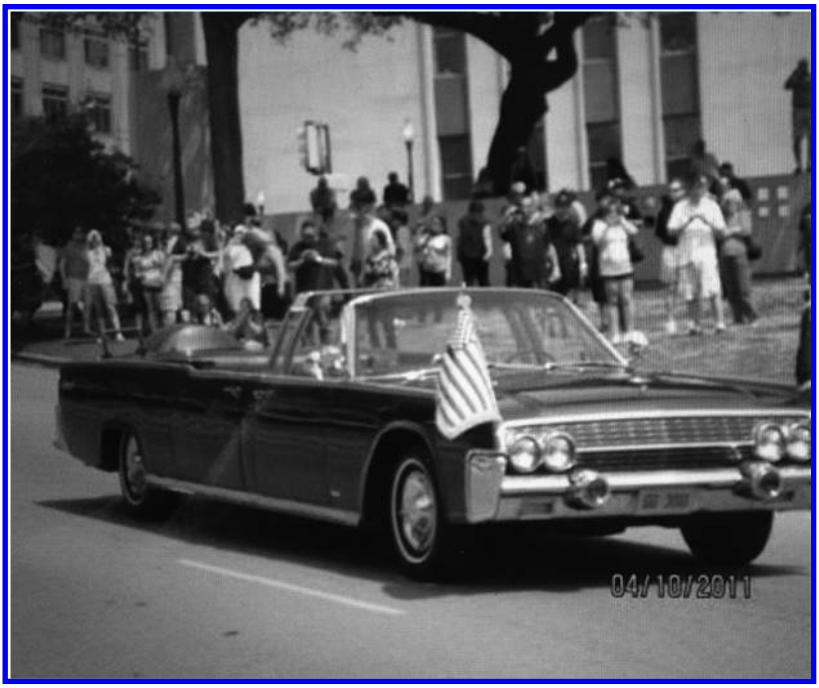

Figure 3.5 JFK assassination reenactment.

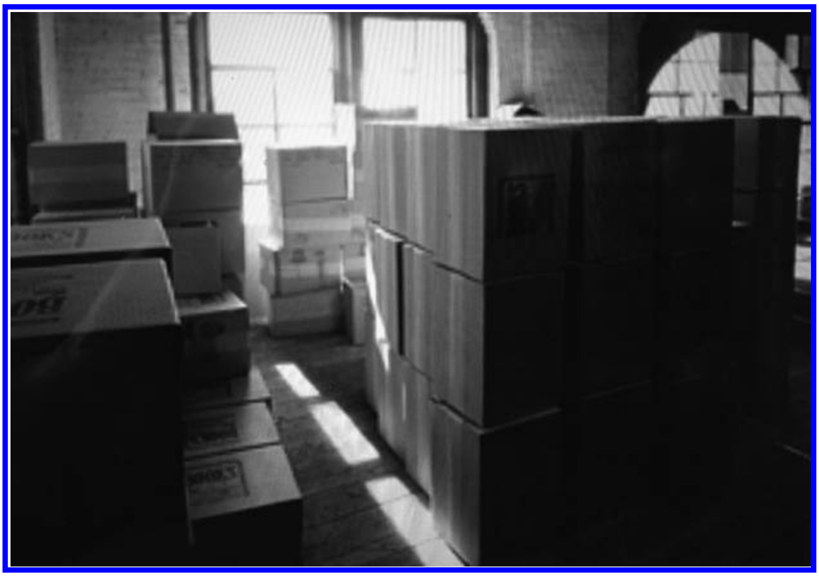

Figure 3.6 Oswald's nest.

Scale Models

Although perhaps more of a demonstrative exhibit than a reenactment, scale models can actually serve to "reenact" a shooting incident quite well. At the Sixth Floor Museum in Dealey Plaza is "The Mother of All Scale Models," a diorama of Dealey Plaza that includes figures, vehicles, trees, and shrubs, as shown in Figures 3.7 and 3.8.

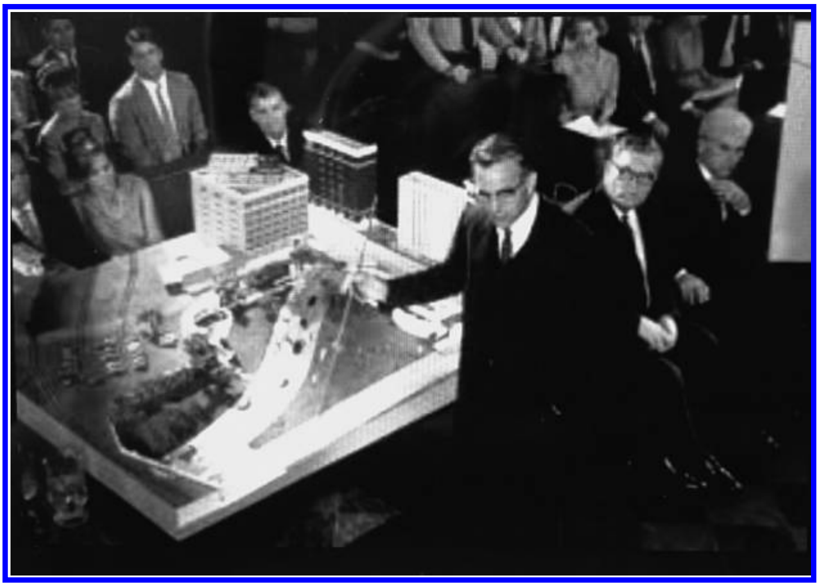

Figure 3.7 Scale model in JFK reconstruction.

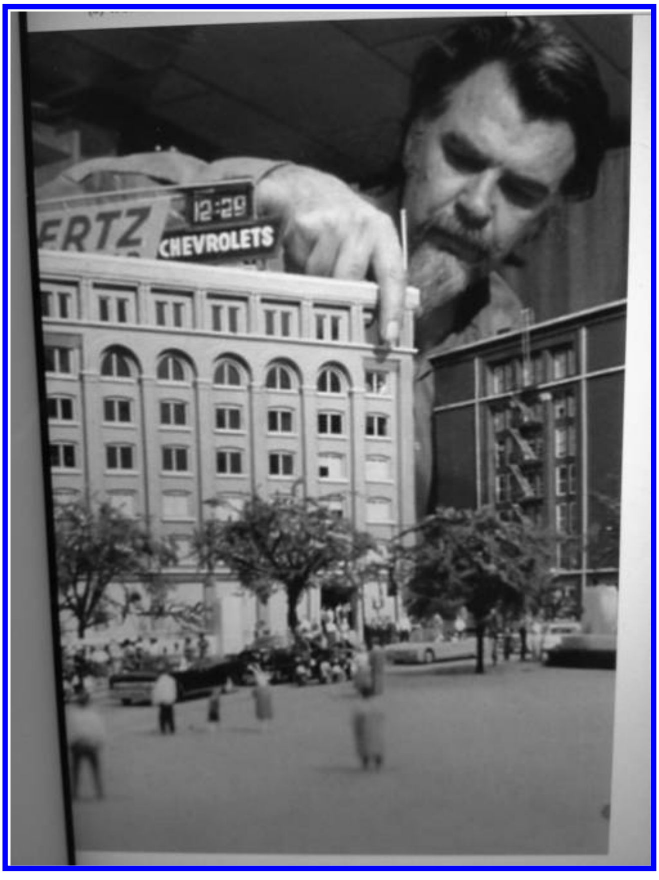
12:29
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Figure 3.8 Scale model in JFK reconstruction example 2.

Preparing a scale model certainly does not have to be as elaborate as the Dealey Plaza model. Thanks to the ready availability of various scale model vehicles, persons, furniture, etc., it is possible to construct scale models in a reasonable amount of time and at a modest cost.

Case Study

The author was involved with the reconstruction of an officer-involved shooting in which the occupant of a pickup truck had been approached by an officer on foot. Upon reaching the driver's door of the parked pickup, the officer stated that he tapped on the door glass in an effort to get the driver to lower the window. The officer stated that the driver suddenly started the truck and turned his front wheels toward the officer, causing the officer to run a few feet, draw his gun and fire a shot as the truck accelerated toward the officer.

The pickup had been parked between two residences in a high crime area notorious for drug dealing. In reviewing the scene, it appeared that the turning radius of the pickup was likely greater than the space between the two buildings. That hypothesis was confirmed through testing. In order to demonstrate the situation to the jury, it was decided to construct a scale model. A visit to a local hobby store produced a model kit of a pickup of the same brand, style and year as that of the suspect (i.e., defendant). Also purchased was a model of an officer. Using foam poster board, models of the two buildings were constructed. Finally, a poster board disk representing the turning radius of the truck was cut out and laid onto the base.

This entire setup was built in a relatively short time, the longest time required being for assembly of the model truck. The foam board buildings were collapsible, allowing transport of the entire setup on a commercial airplane for the trip to court (Figure 3.9). The jury was able to easily see that the officer could not have been run over by the truck given the space limitations at the scene. A reduced charge for the defendant resulted.

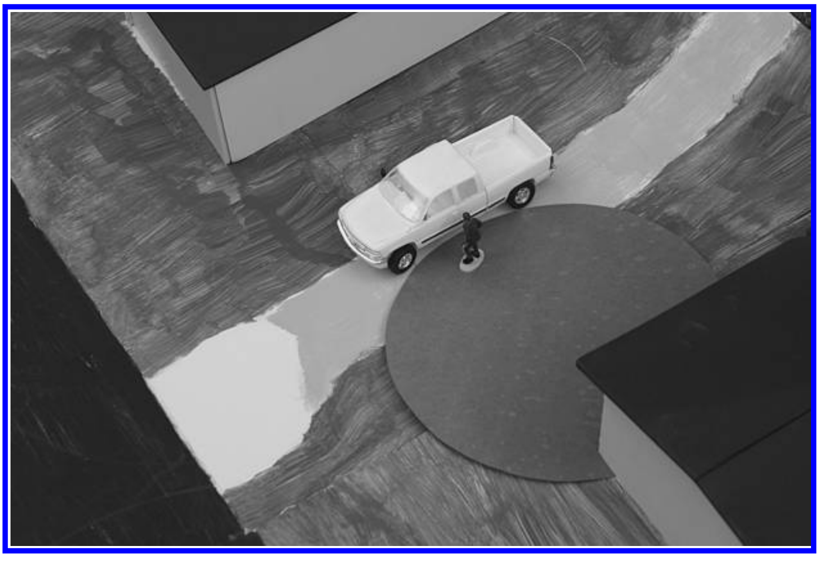

Figure 3.9 Portable scale model.

Computer Animation

The author was first involved in a computer animation effort in 1996 during a high profile officer-involved shooting case. Computer animation was a fairly novel thing at the time and not something that was widely available. The police agency that had hired the author was being sued and wished to exhaust all possible avenues in its effort to turn back the lawsuit.

The end result was a fairly rudimentary piece of work that was almost comical in terms of the appearances and depictions of the movement of the individuals being portrayed, in spite of having been prepared by a Hollywood production company. As one officer noted upon viewing it at the time “It looks like Michael Jackson doing the moonwalk.” Because of that and some other issues, it was decided not to offer the animation into evidence.

Today’s computer animations offer a high level of realism that far surpasses anything from “back in the day.” Computer animations basically allow a jury to visually experience an incident for themselves. When properly prepared, computer animations give a true representation of the spatial orientations of scenes and everyone and everything present. Juries have come to expect computer animations to such a degree that a number of major police agencies now have personnel on staff that can produce them rather than having to rely on outside vendors.

For agencies that must seek out private companies to produce their computer animations, a quick Internet search for “forensic computer animation services” will yield a rather disappointingly small number of offerings and many times only in another state. As might be expected, although the quality has gone up considerably, so has the cost. Some examples of modern computer animations are shown in Figures 3.10 and 3.11.

Time Line Development

An extremely important aspect of case analysis, time line development, is something that depends on good documentation, a sharp eye, and a good knowledge base. The proper documentation of time sensitive details is typically built into the reporting format of a

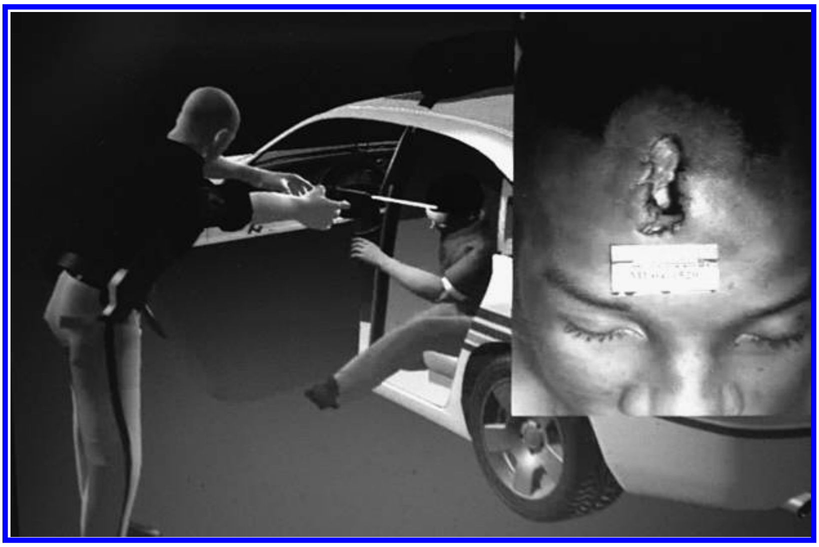

Figure 3.10 Computer animation example 1.

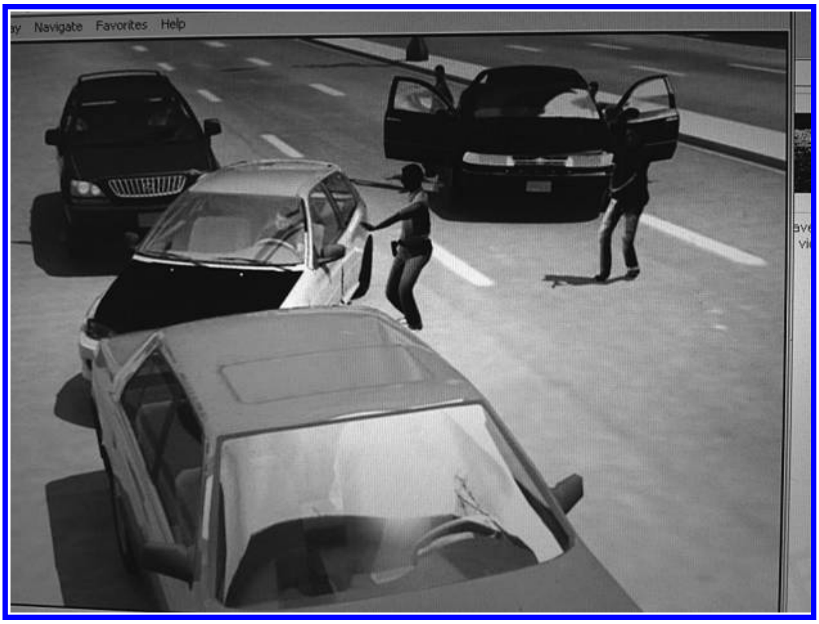

Figure 3.11 Computer animation example 2.

police agency. Standard reporting format includes the entering into report templates of the various time markers associated with a case (e.g., time call came in, arrival time of responding officers, approximate time of incident under investigation, time of arrival of nonpolice responders, time scene was cleared).

It is up to the astute investigator to recognize and properly document (i.e., written notes, sketches, and photographs) time-sensitive aspects of the physical evidence at the scene. Through proper training and experience, an investigator will be able to recognize pertinent details that do not appear to fit the time-related statements made by witnesses.

For example, a first officer arriving at a shooting scene is advised by the reporting person that the victim of a gunshot wound to the head "shot himself about 30 minutes ago." Upon surveying the scene during her preliminary walkthrough, the officer notes that only dried blood is present. Given that the temperature is approximately 25°C (comfortable room temperature) within the scene, the officer notes the apparent discrepancy and brings it to the attention of the later arriving detective and crime scene investigators.

Since the time for a single drop of blood to dry under the conditions at the scene would probably be more like an hour rather than the "30 minutes" stated, further investigation is needed. Of course, the "30 minutes" estimate may be faulty, and there is really no time concern at all. But failing to note the apparent discrepancy and doing nothing to attempt to resolve it is inexcusable. Unfortunately, this type of inattention to detail at crime scenes happens far too frequently.

Some of the most telling aspects of death scenes, as far as indicators of the passage of time, are not always understood or recognized by investigators because of improper training and lack of experience. The situation is exacerbated by "the carpenter–plumber syndrome" (i.e., "I am the carpenter and that is a job for the plumber") when applied at shooting scenes.

There are several manifestations of the passage of some period of time that investigators need to be aware of and be able to recognize at death scenes.

Dried/Drying Blood

Blood on surfaces, whether single drops or pools, starts drying from the outside. A completely dried bloodstain may require an hour or more to do so, depending on atmospheric and substrate conditions. Obviously, for a large pool of blood to have dried, hours may have elapsed unless there are "unusual" circumstances. In any event, testing under similar circumstances should be carried out before rendering any finite opinions with regard to time passage, but it is totally appropriate to raise questions concerning apparent time intervals.

Clotted Blood

Blood outside the body takes varying times to clot, depending on the type of bloodshed and the scene dynamics. It is not possible, therefore, to set exact times for clotting as a general rule. If an investigator notes a combination of unclotted blood and clotted blood at a scene, a lapse in the shedding of blood may have occurred, after which bloodshed resumes.

Rigor Mortis (the Stiffness of Death)

Rigor mortis is the stiffening of the body as a result of the depletion of the biochemical facilitator of muscle movement adenosine triphosphate (ATP). According to DiMaio and DiMaio [1], rigor mortis usually begins 2–4 hours after death, first appearing in the muscles of the jaw. It fully develops in 6–12 hours, but times can vary considerably. Rigor mortis may be manifested immediately in rare instances (cadaveric spasm), as seen in Figure 3.12. Rigor mortis begins to resolve itself following the onset of decomposition.

Livor Mortis (the Color of Death)

The postmortem pooling of blood following death produces a reddish purple coloration in dependent areas of the body due to gravity (blood moves to the lowest area once the heart stops pumping). DiMaio and DiMaio list the visible onset of lividity at 30 minutes to 2 hours after death. Areas of a body that are pressed against hard objects or have tight clothing around them display blanching.

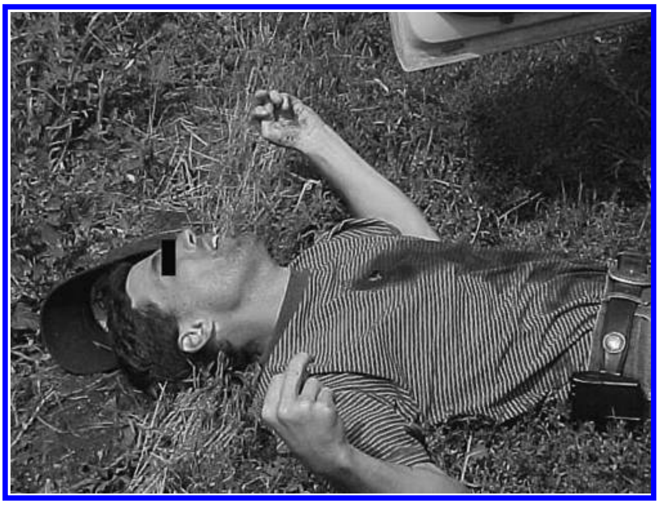

Figure 3.12 Cadaveric spasm.

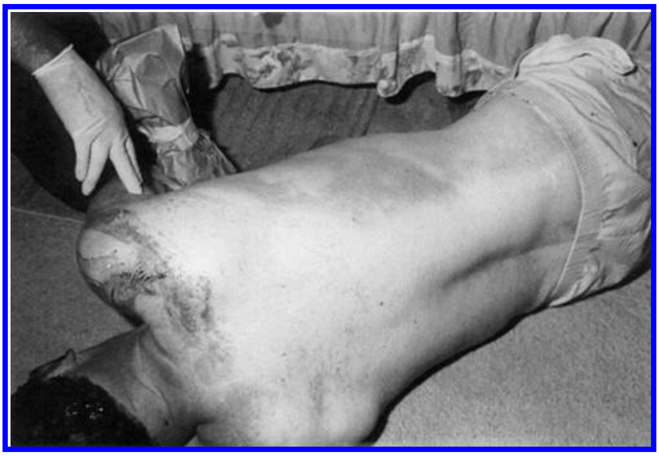

Figure 3.13 Lividity (right side).

At about 8–12 hours, lividity becomes "fixed" (before that, pressing causes blanching). Thus, fixed lividity "out of context" indicates body repositioning after death. This is shown in Figure 3.13.

Case Study

Let us return to the case we reviewed under "Off-Scene Evaluation and Documentation" involving the girl her boyfriend reported as having shot herself in the back of the head. He had told the first officer that the incident had taken place approximately 30 minutes before the officer's arrival. The officer noted that all the blood present on the dead girl's body, on the floor, and on top of a nearby clothes hamper appeared to be completely dry.

The first officer also noted that although the girl was lying on her side, she had what appeared to be postmortem lividity on her buttocks (Figure 3.14). When the body was rolled over, it was realized that her extremities were stiff (i.e., rigor mortis had set in). The first officer appropriately pointed out these observations to the detective once he arrived.

It is clear from the combination of indicators of time passage here (i.e., drying of blood, livor mortis, and rigor mortis) that considerably more time had passed than 30 minutes. Barring cadaveric spasm, rigor mortis required the greatest passage of time in this instance. It is neither important nor appropriate to try to state any more in the way of a specific time interval since death here. The important thing is the recognition that the stated time interval of 30 minutes appears inconsistent with the observed conditions of the scene and the body.

Other Body Indicators

Other indicators of time since death typically fall into the category of postmortem examinations by a death investigator/forensic pathologist. These include body temperature, biochemical changes, gastric contents, and insect activity.

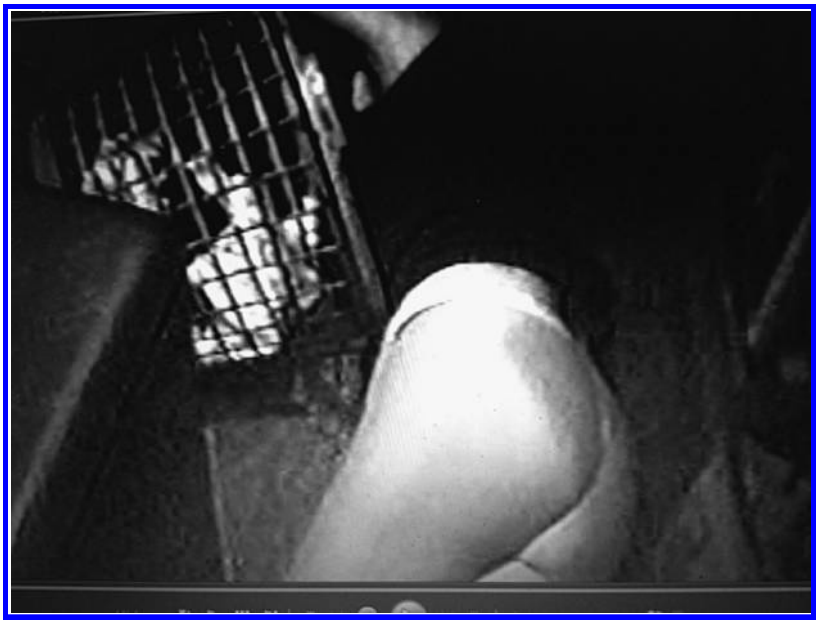

Figure 3.14 Lividity on buttocks.

Other Scene Indicators

There are numerous potential indicators of time of death that the alert investigator may see at the scene. These include

1. Newspapers/mail uncollected
2. Empty garbage cans not brought from the street
3. Outside/inside lights on in full daylight
4. Food on stove/microwave
5. Plates with partially served/eaten food
6. Victim's state of dress
7. Candles burning
8. Water in tub still warm
9. Pets inappropriately out or in residence
10. Last sightings by family/friends
11. Radio/television on

Case Study

A retired governmental employee was found on the living room floor of her residence dead of a knife wound to the neck (the knife still protruding from her neck) at around 3:00 P.M. on a Sunday. There was a container of orange juice on her kitchen counter beside a clean glass. A convection oven nearby was standing open with a wire rack holding already toasted cinnamon rolls sitting on top. A pot of hot coffee was in a coffeemaker and an unused cup was nearby. The Sunday paper was strewn across the floor near an overturned foot stool. The front porch light was on. The victim was dressed in pajamas, a house coat, and slippers. There was no sign of forced entry.

It did not take much detective work for investigators to conclude that the lady must have just gotten up, fixed some breakfast, gone out the front door, and retrieved her morning paper when someone came to her door. She may have let the person in or the person came in forcefully and stabbed her.

Although this was not a shooting incident, the scene indicators would serve equally well if it were. That is all contingent on no alteration of the scene (at least not before proper documentation) by the first responders.

Exercises

1. The O.J. Simpson case of the 1990s involved the murder of O.J.'s estranged wife Nicole Brown Simpson and a friend and waiter at a restaurant Nicole frequented, Ron Goldman. Both Nicole and Ron were found in the front yard of Nicole's residence with their throats cut ear to ear. Nicole was dressed in a black dress with short sleeves. She wore no shoes. Ron was dressed in a jacket, long-sleeved shirt, and long pants, and wore boots. Investigators arrived to find a bowl of still partially frozen ice cream on the stairs inside that led to the second story. Candles were burning around the downstairs master bathtub that had water still warm to the touch. Soft music was playing on the interior stereo system. Both of O.J. and Nicole's young children were asleep in their bedrooms upstairs. The front door was standing open (Figure 3.15).

   What does all this tell you as to the sequence of events leading up to the deaths of Nicole and Ron?

   Answer: The lack of shoes, no jacket and the candles, music, and bath water all suggest Nicole was home and preparing to take a bath. The ice cream suggests she had just gotten it when Ron came to the door and she set it down on the stairs to answer the door.

   Ron's mode of dress is consistent with him having just arrived. The fact that both Nicole's and Ron's bodies were outside and the front door was standing open suggests that Ron and Nicole were probably attacked as they stood in the doorway, before Ron entered.

   The bowl of ice cream offered an unusual opportunity to establish the approximate time elapsed because it was left out of the freezer. Although apparently not done, it would have been fairly easy (assuming there was still ice cream in the freezer) to take a similar quantity of ice cream, put in the same or a similar bowl, set it down on the same stair and determine how much time was required to get a similar state of melting. A photograph needed to be taken of the "evidence" ice cream immediately by the first responding officer (which was not done either).
2. A young man is found in his bedroom dead of a contact gunshot wound to the right temple. His body is slumped back into his closet, a .44 Magnum revolver lying on the floor next to him. The case for the gun is on the floor along with five live rounds lying loose in the open case. There is also an ammunition box in the gun case with six rounds missing. His two roommates called 911 and said they had just arrived at the apartment after being gone for the weekend (it is a three-bedroom apartment and they are all college students). Three empty beer cans are

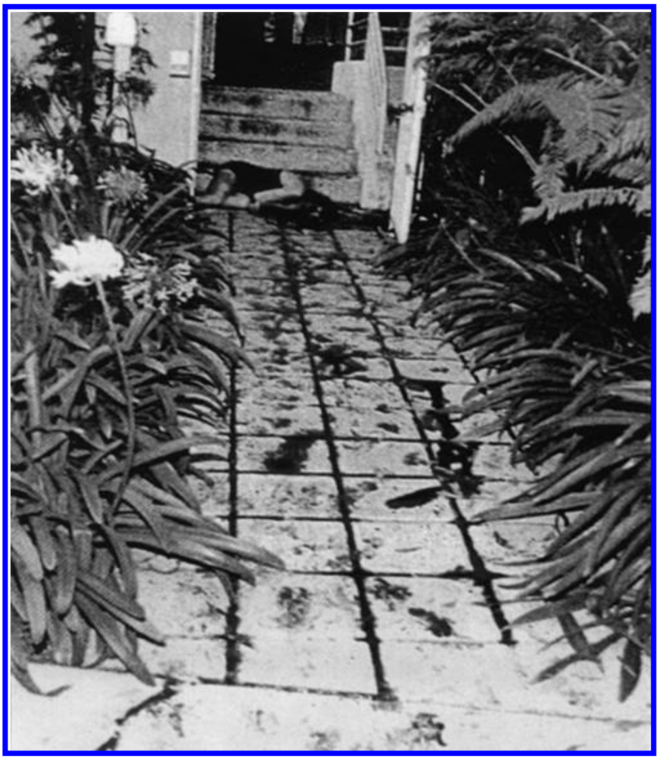

Figure 3.15 O.J. Simpson crime scene.

found on the closet shelf above the body (three unopened cans of beer were found in the decedent's car). A single fired .44 Magnum cartridge case is found beneath the hammer of the revolver. The deceased is determined to have a 0.17 blood alcohol level, and dextromethorphan is found in the blood. The decedent is a Mormon and not known to drink alcohol or abuse drugs.

What should be done in this case in terms of preparing a time line? (Prepare a list of the information that should have been documented using scene images depicted in Figures 3.16 through 3.18.)

What in the way of off-scene investigative efforts are needed here?

Answer: The following information needs to be determined in order to be able to establish whether either of the roommates might have been present around the time of death of the decedent.

a. Time 911 call came in.
b. Time both roommates last were at the apartment.
c. Approximate time of death of decedent (using all the various available means).
d. Canvass the apartments to determine last time the decedent was seen alive.
e. Check for surveillance cameras in the area.
f. Determine if anyone heard the shot and, if so, approximately when.

Given that the decedent was Mormon and not known to abuse alcohol or other drugs and yet had a blood alcohol level of 0.17 (acute intoxication) raises real questions about how he got that way, especially since only three empty beer cans were present. Because there were three unopened cans of beer found in his car, it is

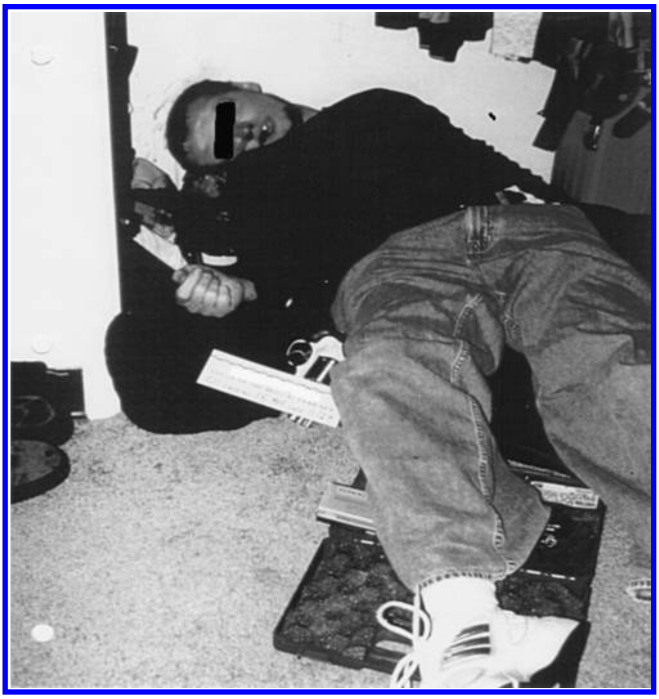

Figure 3.16 Body in closet.

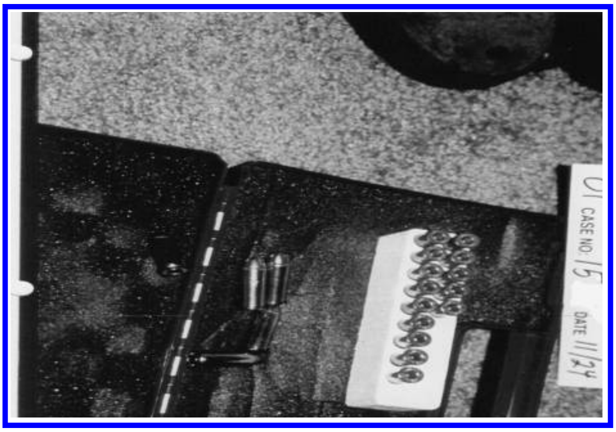

Figure 3.17 Gun case.

highly likely that the beer came from a nearby convenience store following the consumption of a significant amount of alcohol earlier. As for the dextromethorphan detected in his blood, the question that must be answered is, did he have a legitimate health issue that he was treating or was it taken for "recreational" purposes?

a. Did he have a cold or the flu?
b. Were there any bottles of dextromethorphan anywhere (medicine cabinet, out in view in any room, in a trash container inside, or outside, in his car)?

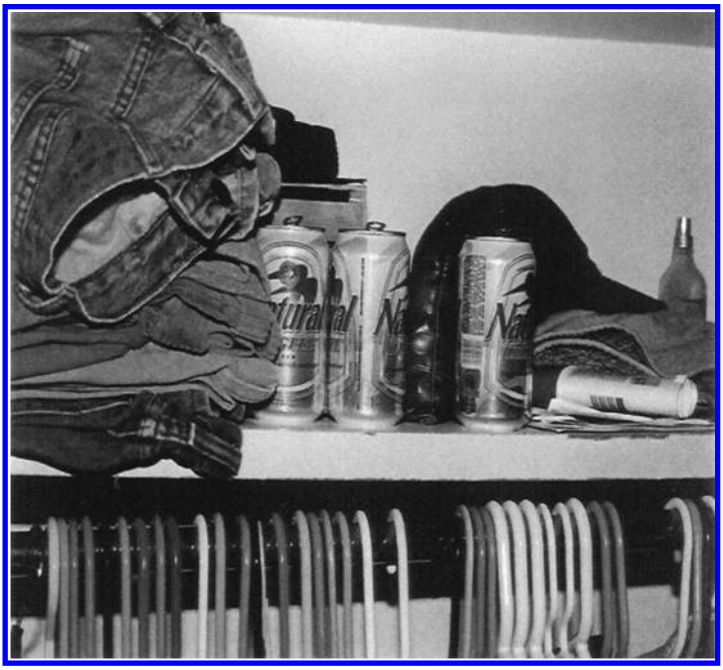

Figure 3.18 Beer cans in closet.

c. Were there any other empty beer cans inside or outside the apartment?
d. Whose DNA is present on the three empty beer cans?
e. Whose DNA is on the full cans and the package?

In case it is not obvious from the various evidence items present, this shooting is highly suggestive of Russian roulette. The first thing that should occur to anyone concerning the "game" is that it is not "an individual sport." In the author's more than 40 years of experience reconstructing shooting incidents, there has always been at least one "spectator" in the cases of Russian roulette he has investigated. Thus, it becomes highly likely that both of the roommates took the decedent out drinking, after which they stopped and purchased a six-pack and each finished one more beer as they went into their apartment to check out the decedent's gun. He gets it out, removes five rounds (leaving one in the cylinder), spins the cylinder, cocks it, places the muzzle against his right temple, and pulls the trigger.

a. Check surveillance videos at nearby convenience stores.
b. Show photographs of each of the three roommates to clerks and ask if they remember any of them.
c. Establish the decedent's knowledge of firearms in general and this revolver in particular.
d. Establish the typical loading status of the revolver.
e. Do primer residue testing on the hands of both roommates (but not the decedent).
f. Determine whose DNA is on the trigger of the revolver.

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Mathematics of Shooting Reconstruction

4

Trigonometry, Geometry, and Shooting Incident Analysis

Trigonometry and geometry provide the mathematical basis for the solution of many shooting incident problems. With this in mind, a review of some of the basic principles of trigonometry and geometry is in order. The word trigonometry simply means the measure of triangles. The word geometry means "earth measure."

Two angles the sum of which is 90° are called complementary angles (Figure 4.1). Two angles whose sum is 180° are known as supplementary angles. When two lines meet perpendicular to each other, two right angles, each 90°, are created.

Triangles are three-sided figures containing three internal angles, the sum of which is 180° (Figure 4.2).

In shooting reconstruction, we typically use a particular type of triangle known as the right triangle. A right triangle is a triangle one angle of which is equal to 90° (Figure 4.3).

If the sum of the angles of a triangle is 180° and one of the angles is 90°, then the sum of the remaining angles is 90° (Figure 4.4).

Greek philosopher and mathematician Pythagoras studied right triangles and deduced the special relationship that exists between the sides of a right triangle. He found that the greater the angle, the longer the side opposite that angle. In a right triangle, the greatest angle is the right (or 90°) angle. Thus, the side opposite the right angle will be the longest side in the right triangle. This side is called the hypotenuse (Figure 4.5).

Pythagoras found that if one takes the length of the hypotenuse of any right triangle and multiplies it by itself ("squares" it), the product will equal the sum of each of the other two sides each multiplied by themselves (Figure 4.6).

For example, suppose we have a triangle with the side lengths as shown (Figure 4.7).

According to the Pythagorean theorem, the length of the hypotenuse (C) squared is equal to the sum of the squares of the other two sides (Figure 4.8).

So, we would have

$$(2.00)^2 = (1.00)^2 + (1.732)^2$$

or

$$4.000 = 1.00 + 3.000$$

The relationships between the various sides and angles of right triangles are expressed in terms of a series of trigonometric functions. These trigonometric functions are very useful for solving various shooting reconstruction problems.

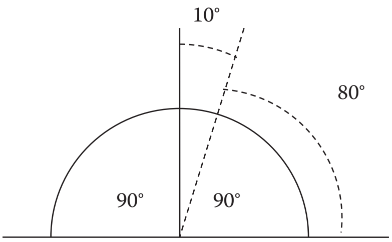


Figure 4.1 Complementary and supplementary angles.

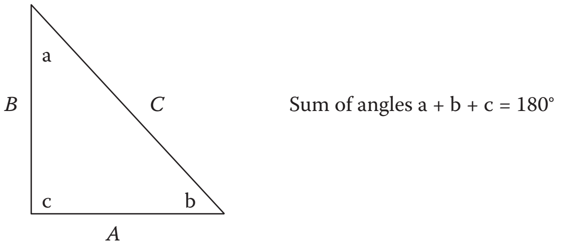

a
B
C
c
b
A
Sum of angles a + b + c = 180°

Figure 4.2 Triangle.

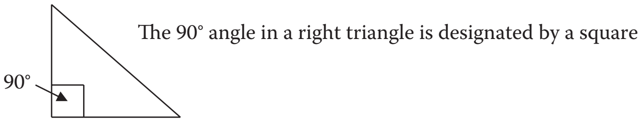

The 90° angle in a right triangle is designated by a square
90°

Figure 4.3 Right triangle.

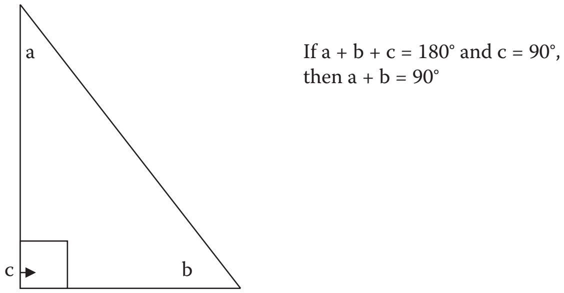

a
If a + b + c = 180° and c = 90°,
then a + b = 90°
c
b

Figure 4.4 Sum of angles in a triangle.

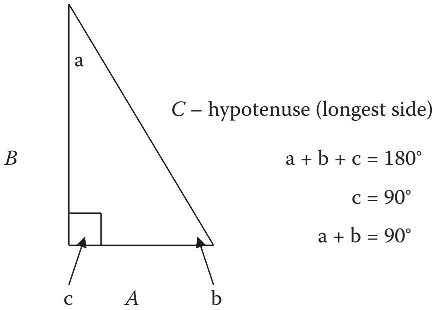

a
C – hypotenuse (longest side)
B
a + b + c = 180°
c = 90°
a + b = 90°
c
A
b

Figure 4.5 Hypotenuse (longest side).

$$C^2 = A^2 + B^2$$

Figure 4.6 The Pythagorean theorem.

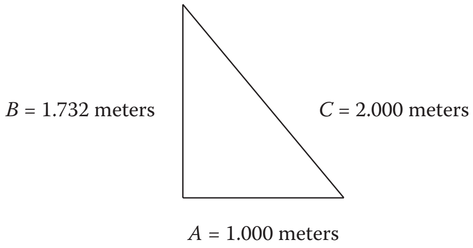

B = 1.732 meters
C = 2.000 meters
A = 1.000 meters

Figure 4.7 Triangle with side lengths $A = 1.0$ meters, $B = 1.732$ meters, and $C = 2.0$ meters.

$$C^2 = A^2 + B^2$$

Figure 4.8 Relation of hypotenuse (C) to the other sides (A and B).

Trigonometric functions are described in terms of the hypotenuse, which has already been defined, the side opposite the angle, and the side adjacent (Figure 4.9).

For angles *a* and *b*, there will be an opposite side, an adjacent side, and the hypotenuse (Figure 4.10).

Using these designations, we will work with three trigonometric functions: sine, cosine, and tangent.

These functions are abbreviated as follows:

Sine—Sin → Cosine—Cos → Tangent—Tan

For each of the angles in a right triangle, these functions are defined in terms of their relationships to their respective opposite and adjacent sides and to the hypotenuse. One must simply remember that the hypotenuse is always the side opposite the 90° angle. In

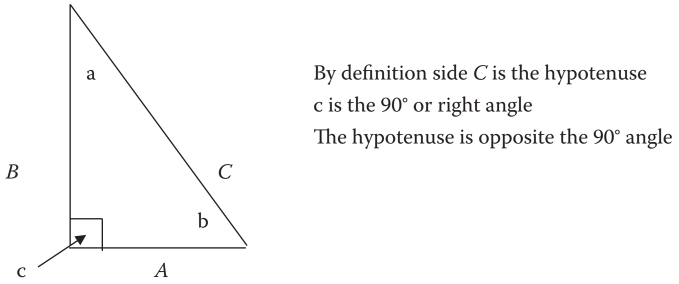

a
B
C
b
c
A
By definition side C is the hypotenuse
c is the 90° or right angle
The hypotenuse is opposite the 90° angle

Figure 4.9 Hypotenuse and right angle (c = 90°).

Angle	Adjacent side	Opposite side	Hypotenuse
a	*B*	*A*	*C*
b	*A*	*B*	*C*

Figure 4.10 Angles and sides of a triangle.

writing mathematical formulas involving angles, the Greek letter theta (θ) is the symbol used to represent any angle.

Sin θ = Length of opposite side/Length of hypotenuse

Cos θ = Length of adjacent side/Length of hypotenuse

Tan θ = Length of opposite side/Length of adjacent side

For any right triangle, the relationships between the sides and angles are represented by these functions. By referring to the preceding chart, the designation of opposite and adjacent sides for a particular angle is apparent (Figure 4.11).

Using our definitions and the given values for sides and angles, we come up with the following:

Sin 30° = Length of opposite side/Length of hypotenuse = 1/2 or 0.5

Sin 60° = Length of opposite side/Length of hypotenuse = 1.732/2 or 0.866

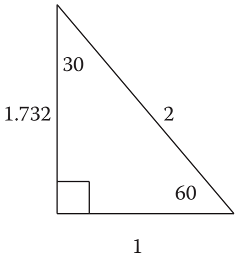
Cos 30° = Length of adjacent side/Length of hypotenuse = 1.732/2 or 0.866

Cos 60° = Length of adjacent side/Length of hypotenuse = 1/2 or 0.5

Tan 30° = Length of opposite side/Length of adjacent side = 1/1.732 or 0.577

Tan 60° = Length of opposite side/Length of adjacent side = 1.732/1 or 1.732

What relationships do you see between sin, cos, and tan? Angles less than 90° are called acute angles. There are always two acute angles in a right triangle. Remembering that the sum of the two acute angles is 90°, these angles are termed complementary angles. Thus, the complement of 30° is 60°, the complement of 20° is 70° and so on. Notice the relationship between the sin of an angle and the cos of its complement. If you know the value of the sin of any angle, you also know the value of the cos of its complementary angle. Also note the relationship between the tan of an angle and the tan of its complementary angle. The relationship between the two is an inverse relationship. Thus, if you know the value of the tan of an angle, the tan of its complementary angle will be the reciprocal.



This is what is known as a standard right triangle where the angles are 30°, 60°, and 90° and side lengths are in the ratio 1 to 1.732 to 2.

Figure 4.11 Standard right triangle.

The Pythagorean theorem and the trigonometric functions are very useful in solving problems associated with shooting reconstructions. At the shooting scene we can construct imaginary right triangles and use them to answer questions. For example, suppose we wish to determine the height of a building that shots were fired from the roof of. It is really unnecessary to call for sophisticated equipment, such as a surveyor's transit, to solve this problem. Using basic equipment that will be discussed in a later chapter, we can establish the angle of inclination from a reference point to the top of the building. The distance from the same reference point to the base of the building is then measured. With these two values, we can then calculate the height of the structure (Figure 4.12).

To solve for the height of the building, we use the tangent function since we know the following:

- The length of the adjacent side of our imaginary triangle and we wish to determine the length of the opposite side
- The formula that we use to solve for the height of the building is

$$\text{Tan } 27° = \text{Length of opposite side/Length of adjacent side}$$

$$\text{Tan } 27° = \text{Height of building/64 feet}$$

By using a handheld scientific calculator, we quickly determine that Tan 27° is 0.51. Substituting this value into our equation and rearranging it, we get

$$\text{Height of building} = 0.51 \times 64 \text{ feet}$$

$$\text{Height of building} = 32.6 \text{ feet}$$

We can use this type of calculation to find the height of virtually anything at a shooting scene. All that is required is a scientific calculator, a tape measure, a tripod, an angle gauge, and a laser. Equipment specifics will be discussed in Chapter 6.

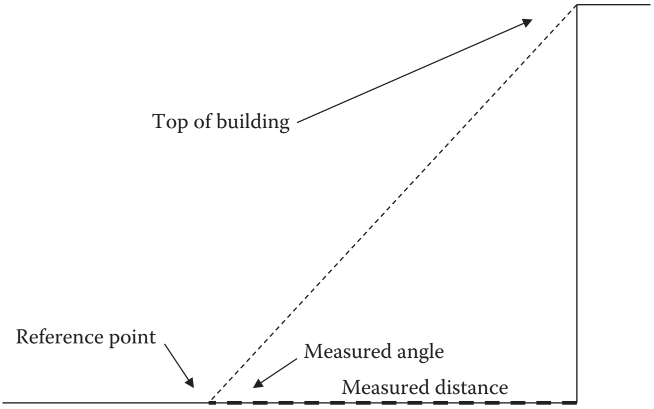


Figure 4.12 Calculation of building height using tangent function.

In the infamous sniper incident at the University of Texas tower in the summer of 1966, Charles Whitman had assembled a veritable arsenal and had ascended to the top of the tower where he began picking off students on the ground. Whitman's initial weapon of choice was a Remington model 700 bolt action rifle in 6-mm caliber fitted with a telescopic sight. From his vantage point some 300 feet above the ground, Whitman was able to pick off students hundreds of yards from the base of the tower. As a student attending summer classes at the University of Texas, I clearly recall walking out of my dormitory on my way to organic chemistry class and hearing what I thought were firecrackers coming from the stadium. I would soon realize that the sound was gunfire coming from the tower. The sound was bouncing off the stadium walls making me think that the stadium was the source.

The scene that I witnessed upon reaching the mall of the University of Texas tower was incomprehensible: students were lying on the ground in pools of blood, students were falling as they were shot, and there was pandemonium everywhere. I noticed a Texas Ranger crouched at the corner of a building shouldering a rifle. Periodically, a shot would ring out as he fired up at the top of the tower. I crouched down a few feet behind him. He briefly turned back and glanced at me but said nothing as he turned his attention back to Whitman and the top of the tower.

The situation was totally out of control. Private citizens were soon returning fire as well. I personally witnessed a man in a service truck pull up near the location that the Texas Ranger and I were at, grab a lever action rifle with no scope from behind the seat and begin firing toward the top of the tower. Given that the distance from his position to Whitman's location was probably at least 300 yards, trying to shoot without the benefit of a telescopic sight was reckless, to say the least.

After what seemed to be an eternity, although in reality was probably 20 minutes or so, a light aircraft could be seen heading toward the tower from off in the distance. The plane began to circle above the tower and automatic weapon fire could be heard. Members of the Texas Department of Public Safety had apparently thought that attaining a position of "higher ground" would be the way to get to Whitman and end it. Once Whitman started returning fire, however, the aircraft departed.

The final resolution came when Austin police officers Martinez and McCoy ascended to the top of the tower via the same elevator that Whitman had used and shot Whitman to death. This was an incredible act of bravery on the part of both men. Those of us who were positioned around the mall saw an arm waving a white handkerchief above the wall at the top of the tower. Not knowing what Martinez and McCoy had just done, we believed it was Whitman surrendering. For some unknown reason, we all rushed toward the tower. It was then that we found out the grisly details of Whitman's trip up the tower as the bodies of his murder victims were brought down. Ultimately, Whitman's body was brought down.

Fourteen people were killed including Whitman's wife and mother. There were anywhere from 31 to 34 injured. The exact number was unclear owing to questions about "friendly fire." Given the firing of high caliber rifles and automatic weapons upward from the ground and from above, it is amazing that more people were not struck by errant rounds.

It is despicable to compliment Whitman in any way, but his shooting skills were incredible. In one instance, a paper boy was shot off his bicycle while riding down the sidewalk some 600 yards from the base of the tower. We can use trigonometry to calculate a number of different aspects of that shot. For example, suppose we wish to determine the minimum distance that the bullet had to travel. The path of a bullet, of course, is parabolic and not a straight line, which is why we are going to be determining the minimum distance as opposed to the actual. However, given the fact that the 6 mm Remington is a very flat shooting weapon that produces only an inch and a quarter bullet rise at 200 yards, we are able to make a pretty close approximation.

We begin by constructing an imaginary right triangle that incorporates the various distances that we have to work with (Figure 4.13).

The wound to the paper boy was approximately 4 feet above the ground as he sat on his bicycle. The height above ground of Whitman's position was approximately 300 feet. Therefore, the height of our right triangle will be 300 minus 4 or 296 feet. For simplicity's sake, we are neglecting any difference in elevation for the paper boy's position relative to the tower. To calculate the minimum distance traveled by the fatal bullet, we use the Pythagorean theorem. In this example, the minimum bullet distance traveled is represented by the hypotenuse of our imaginary right triangle. Thus, our calculation is as follows:

Pythagorean theorem

$$C^2 = A^2 + B^2$$

$$C^2 = (296)^2 + (1800)^2$$

$$C^2 = 87{,}616 + 3{,}240{,}000 = 3{,}327{,}616$$

C is equal to the square root of 3,327,616 or 1824 feet.

We can also calculate the angle of declination of Whitman's rifle for the shot by recalling that when two parallel lines are intersected by a diagonal line, the alternating angles are equal (Figure 4.14).

We use this information because we will be calculating the base angle (θ) of our imaginary right triangle, and that angle will equal the angle of declination of the rifle (Figure 4.15). For this problem, we will use the tangent function to solve for θ, which is equal to the angle of declination.

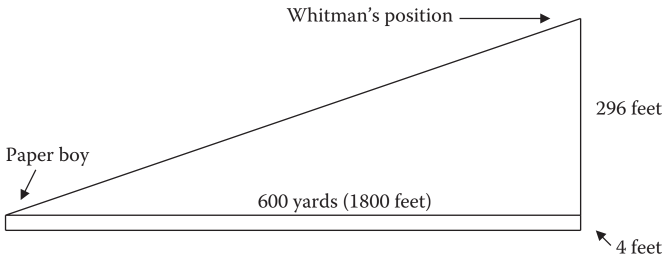


Figure 4.13 Imaginary right triangle incorporating various distances involved in the problem.

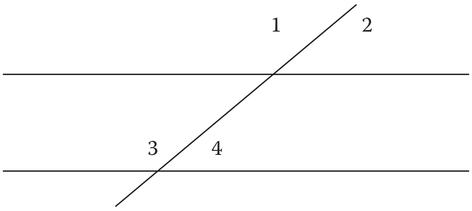


Figure 4.14 When two parallel lines are intersected by a diagonal line, alternating angles are equal. Thus, angle 1 = angle 3 and angle 2 = angle 4.

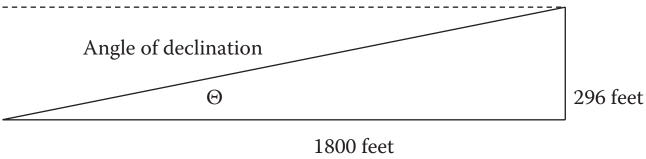


Figure 4.15 Calculating the base angle (θ) of the imaginary right triangle, which is equal to the angle of declination of the rifle.

$$\text{Tan } \theta = 296/1800$$

$$\text{Tan } \theta = 0.164444$$

Angle θ is then found by determining the arc tan or inverse tangent of 0.164444. This is easily accomplished using a scientific calculator. Looking at the keypad of a scientific calculator, you will note that above the keys for sin, cos, and tan is the symbol for the arc or inverse relationship (i.e., $\sin^{-1}$, $\cos^{-1}$, and $\tan^{-1}$). In the upper left-hand corner of the keypad, there will be a key marked “2nd” or “shift”. By entering the numerical value, in this case 0.164444, depressing the “2nd” or “shift” key and then depressing the “tan” key we can determine the arc tan (inverse tan).

$$\text{Arc Tan } 0.164444 = 9.3°$$

In an effort to simplify this as much as possible, it should be pointed out that the preceding equation can be “translated” into “The angle whose tangent is 0.164444 is 9.3 degrees.”

Therefore, the angle of declination that Whitman used to shoot the paper boy off his bicycle was 9.3°.

Calculation of Impact Angles

When a bullet or shot pellet penetrates a substrate, the angle of impact (the interior angle between the bullet axis and the substrate) may be calculated by using the bullet/pellet hole dimensions. The shape of the hole provides us with information as to the general impact angle. Bullets/pellets penetrating substrates at or near 90° generally produce round holes. Any angle of impact significantly less than 90° results in an oval or oblong hole. The smaller the angle of impact, the longer the hole. In general, the width of the hole approximates the caliber (cross-sectional diameter) of the projectile. Naturally, this will vary with bullet design/construction and substrate properties (i.e., texture, hardness, thickness). This principle is illustrated in Figure 4.16.

The width and length of the hole are, therefore, a function of the caliber and the impact angle, respectively. Once again, we use trigonometry to derive the relationship between impact angle, hole width, and hole length (Figure 4.17).

Note that the hole length forms the hypotenuse of the right triangle that we have constructed, and the side opposite the angle of impact is the same as the hole width. In case you are wondering why this is so, it is because we constructed our right triangle that way (i.e., it was not by mere coincidence). We use the sine function to express the relationship between the impact angle and the width and length of the bullet hole.

Sin of angle of impact = bullet hole width/bullet hole length

As an example, let us suppose that we measure the width of a bullet hole in a thin sheet of aluminum and determine it to be 0.46 inch. We next measure the bullet hole length and find it to be 0.91 inch. The sine of the angle of impact is hole width divided by hole length (0.46/0.92), which is equal to 0.50. This is the sine angle of impact, not the actual angle. To determine the angle, we must determine the inverse or arc sine of 0.50. That is, we must determine the value of the angle whose sine is 0.50 by using a scientific calculator. The sine value of 0.50 is entered, then the second function or shift key is depressed followed by the

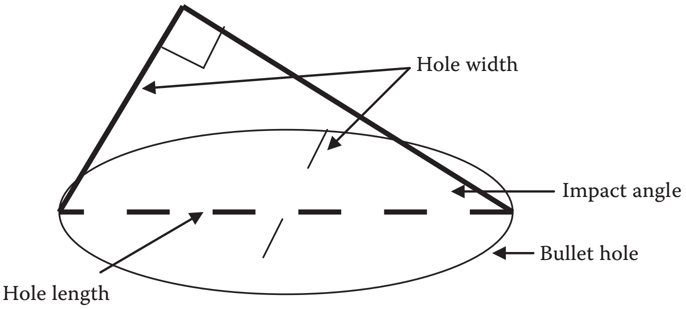


Figure 4.16 Hole width approximates the caliber (cross-sectional diameter) of the projectile, which varies according to bullet design/construction and substrate properties (i.e., texture, hardness, thickness).

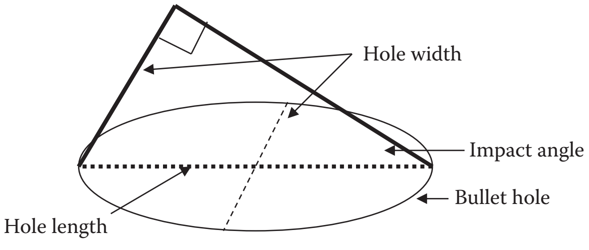


Figure 4.17 Relationship between impact angle, hole width, and hole length.

sin key, and the value of the impact angle—in this case, 30°—appears in the window. This is all summarized below:

Step 1: Divide width by length: 0.46/0.92 = 0.50.
Step 2: Depress the 2nd or shift key.
Step 3: Depress the sin key: the impact angle 30° appears in the window.

Note that if you depress the sin key with 30° showing in the window, the value 0.50 reappears. This is the equivalent of "toggling" back and forth between the numerical value of the sine and the angle.

The value of the bullet hole width of 0.46 inch suggests the possibility of .45 caliber. It is unwise to speculate as to specific calibers, however, because bullets may expand as they perforate substrates, resulting in slightly oversized holes. Soft substrates, such as wood or cardboard, will likely contract slightly following bullet passage. The margins of bullet holes in certain materials, such as sheet rock or plywood, will frequently be irregular, making accurate measurement difficult (see Figure 4.18).

Angles of impact determined through calculation, like most other aspects of shooting reconstruction, are approximations not absolutes and should be considered as such. As most shootings take place at close range, however, this does not constitute a major concern. If we are trying to establish a shooter position 500 or 1000 yards away using an impact angle we have calculated, a few degrees makes a more substantial difference. It then becomes necessary to consider a possible range of positions. Based on repeated experiments with known shooting positions, one can typically expect less than 10° of error (plus or minus) in the calculated value versus the actual value. More often than not, an error of no more than ±5° is possible if the hole margins are well defined, and the measurements are carefully and accurately made.

Shotgun pellet patterns can also be used to calculate approximate angles of impact by measuring the width and length of the pellet pattern perimeter. If buckshot is involved, individual pellet holes can often also be used by measuring their individual widths and lengths. Birdshot, being much smaller in diameter, does not lend itself very well to individual pellet measurement. Additional considerations involving shot shell patterns are discussed in Chapter 6.

When a bullet or shot pellet impacts a surface, there will actually be two angles involving the axis of the projectile and the substrate. In addition to the angle of impact or interior

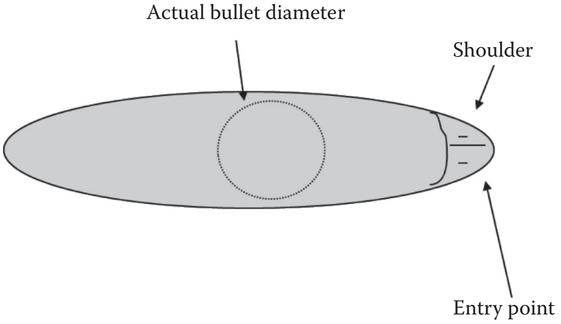


Figure 4.18 Typical comparison of bullet hole width to bullet diameter.

angle we have been discussing, there will also be a lateral angle. The lateral angle represents the angle of the projectile axis relative to the axis of the substrate. For an illustration and further explanation, the reader is referred to Chapter 4.

A rancher is arrested following the shooting of a trespasser on his property. The rancher uses his land as a deer hunting preserve and, as such, it is surrounded by an 8-feet-tall fence designed to keep his deer herd in. According to the rancher, he was walking along a dirt road within his fence line at dusk carrying a 25-06 caliber bolt action rifle with his right hand when he rounded a bend in the road and observed two males approximately 75 yards ahead of him. He stated that he yelled out “Stop,” at which time one of the two males took off running, whereas the other whirled around with what the rancher perceived to be a handgun (it turned out to be a water jug). The rancher said that as he started to raise the rifle with his right hand, the weapon discharged and the apparent assailant fell to the ground with what turned out to be a bullet wound to the calf of his left leg.

All the victim stated that he could recall was seeing a flash and feeling a burning sensation in his left leg. He stated he and his friend had merely been trying to take a short cut across the property. He admitted to climbing the fence to get into the property.

The rancher maintained that he had not intentionally fired the gun but that he did have his finger on the trigger as he had instinctively raised it in response to the perceived threat from the trespasser. Because of a long history of area ranchers shooting trespassers, attempted murder charges were filed in an effort to “send a message.”

The question to be answered was whether a ricochet could account for the trespasser’s injury. The wound was a perforating injury, and the responsible bullet was never recovered. No photographs were taken of the wound and no detailed notes were made by the treating physician.

The reconstruction of the shooting began with an examination of the rifle and the determination that the trigger pull was only 1.5 pounds. After this examination, a reenactment was carried out with a primed case (no powder charge or bullet present) in the chamber and the safety off. As described by the rancher, the weapon was held in the right hand with the muzzle toward the ground and with the forefinger on the trigger. The idea here was to test the hypothesis that the weight of the gun could produce discharge as the weapon was raised while keeping the finger on the trigger. This was determined to repeatedly occur. This testing was videotaped for documentation purposes. A visit to the scene of the incident was made for purposes of evaluating the terrain and taking measurements.

The terrain was relatively flat from the rancher’s position toward the victim’s position. The road consisted of soft mud. A possible bullet strike was located. The distance from the rancher’s stated position to the bullet strike and also to the location of a blood stain was determined. Using the height of the rancher and his stated position, an approximate angle of impact with the ground was determined to be 20° by constructing an imaginary right triangle and utilizing the fact that when parallel lines are intersected by a diagonal line, alternating angles are equal (Figure 4.19).

A similar imaginary right triangle was constructed using the position of the bullet strike mark, the position of the blood stain, and the height of the victim’s injury above the ground (Figure 4.20).

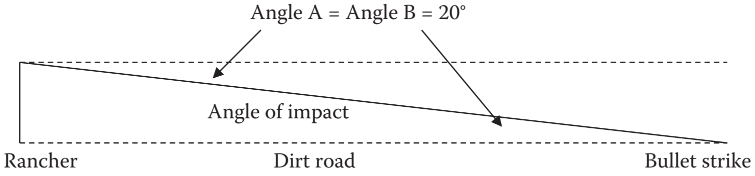


Figure 4.19 Approximate angle of impact with the ground was calculated to be 20°.

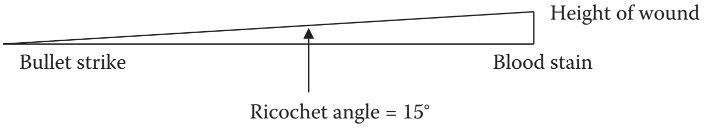


Figure 4.20 Constructing an imaginary right triangle using the positions of bullet strike, bloodstain, and height of the victim's injury (above the ground) to check for the probability of a ricochet.

Based on the examination of the weapon, the reenactment, and the reconstruction, it was determined that a ricochet was probable. The light trigger pull of the weapon was consistent with unintentional discharge, but the rancher having intentionally fired a "warning shot" that produced the ricochet could not be ruled out.

We can use measurements of bullet ricochet creases and marks to establish the approximate angle of impact in the same way. Using a variety of substrates, along with a variety of bullet calibers and designs, the author has found that bullet ricochet marks and creases can be measured as to length and width and approximate impact angles determined. The key is to have a ricochet mark/crease that is symmetrical and, thus, conducive to length/width measurements. When the ricochet mark/crease is other than symmetrical, estimations of length in particular are required. Obviously, when estimations are required, the results obtained will be somewhat less accurate. The technique for using a laser protractor to establish approximate shooter position using the calculated impact angle for a ricochet mark/crease will be discussed in Chapter 11.

It is also useful to be able to calculate the *x,y* angles of impact.

Other Calculations

There are various other calculations that are of value in shooting reconstructions. From time to time, the rate of fire of a weapon is a factor in determining whether a certain scenario is possible. Typically, where moving targets are involved, the question is whether a particular number of shots are possible within a certain time frame. The combination of rate of fire and time of target availability forms the basis for the determination as to feasibility.

Rate of fire may be established through test firing, as will be discussed in a following section, or by referring to manufacturer's data when available. For semiautomatic weapons, such determinations are clearly subjective, because one cannot precisely duplicate what a suspect can or cannot physically accomplish with regard to rate of fire of a weapon. It is, however, realistically possible to establish a maximum rate of fire and work with that.

Time of target availability can be derived from a variety of indicators. Vehicles are frequently involved in shootings and become the moving targets to be considered in those instances. Field of view and estimated speed offer the means for estimating target availability times. Suppose a vehicle was known to be traveling at 60 mph when it was struck by two bullets that pass through the windshield and are not recovered. Also assume that there is a field of view of 50 feet. The first question to be answered is how long the vehicle presents itself as a target. This is found by converting the speed in miles per hour into feet per second. We do this because our field of view is expressed in feet, and rate of fire is typically expressed in rounds per second.

$$60 \text{ mph} \times 5280 \text{ feet/mile} \times 1 \text{ hour/60 minutes} \times 1 \text{ minute/60 seconds} = 88 \text{ feet/second}$$

With a field of view of 50 feet, we must divide by our speed in feet/second in order to determine the time the target is available.

$$50 \text{ feet}/88 \text{ feet/second} = 0.56 \text{ second}$$

The second question that must be answered is whether the weapon involved could have fired the two shots within the available time. If we have a weapon capable of firing four shots per second, for example, we multiply the rate of fire by the time the target is available,

$$4 \text{ shots/second} \times 0.56 \text{ second} = 2.24 \text{ shots}$$

Thus, a total of two shots could have been fired. Had the result been a little less definitive, say 1.75 shots, our conclusion would have been accordingly less definitive. Additional information would be required in order for a conclusion to be reached.

Three teenagers are riding around on a gravel road in a rural area at dusk. They are drinking beer and backfiring their Jeep by turning the ignition switch on and off. As they approach a residence along the road, they are unaware that the owner is standing in his front yard armed with a .22 caliber semiautomatic rifle. According to the owner, upon hearing what he thinks is a gunshot coming from the roadway, he “hits the deck” chest first while holding the rifle up above the ground and “may have accidentally fired a shot” because he had his thumb inside the trigger guard. A single fired .22 caliber cartridge case will later be recovered from the area he claims he fell to the ground at.

The driver of the Jeep received a fatal gunshot behind his left ear, slumped forward, and crashed the Jeep into a parked vehicle on the side of the road a short distance away. The two passengers in the Jeep did not see or hear anything other than seeing the driver suddenly slump forward.

Ultimately, two additional bullet strikes to the Jeep were discovered. The question then became whether three shots could have been fired from the position the shooter was in, given the “window of opportunity” presented by the Jeep as it moved across an opening in the underbrush in front of the residence.

The weapon in this case was a Springfield Arms .22 long rifle semiautomatic rifle. A series of test firings was carried out to allow the determination that the rifle was capable of firing up to five shots per second.

An examination of the damage to the Jeep and the damage to the parked vehicle that was struck allowed the accident reconstruction unit to estimate the Jeep's speed at impact to be 25 mph. Because the distance from the crash site to where the Jeep was likely first struck by gunfire was about two car lengths, it was assumed that the Jeep's speed just before the shooting was approximately 25 mph as well. To calculate the feasibility of the shooter having been able to fire three shots at the Jeep once again requires calculating the time of target availability and relating it to the maximum rate of fire of the weapon.

25 mph × 5280 feet/mile × 1 hour/60 minutes × 1 minute/60 seconds = 36 feet/second

The field of view of the roadway from the shooter's position was approximately 50 feet.

50 feet divided by 36 feet/second = 1.38 seconds

That is the time that the target was visible from the shooter's position. Using the rate of fire of the Springfield rifle, the feasibility of three shots having been fired may be determined.

5 shots/second × 1.38 seconds = 6.9 shots

Therefore, at least six shots could have been fired. Because the question was whether or not three shots could have been fired, it can be stated with confidence that there was ample time to accomplish the required shots.

It is not uncommon to find bullets at shooting scenes during the course of the scene investigation. For purposes of reconstructing the shooting, it is important to be able to identify the source of each bullet located. The bullets recovered at shooting scenes are frequently distorted and/or fragmented making caliber determination very difficult. Most distorted bullet bases take on somewhat of an oval shape. This can, of course, vary considerably from bullet to bullet, but the estimation of caliber can be accomplished by measuring the long and short axes of the oval-shaped base. A "best fit" oval may be approximated when distortion results in a very irregular contour.

The formula for the calculation of the perimeter of an oval provides the means for calculating the bullet diameter (i.e., caliber).

The perimeter of an oval, P, is closely approximated using the formula:

$$P \approx \pi\sqrt{2(a^2+b^2)-(a-b)^2/2}$$

We know that the perimeter of a circle is found by multiplying the diameter by the constant π:

$$P = \pi d$$

From this, we can derive the formula for the diameter of the circle represented by the oval:

$$\text{Diameter of the circle (oval)} \approx \sqrt{2(a^2+b^2)-(a-b)^2/2}$$

The "idealized" diameter of the oval equates to the caliber of the distorted bullet. The values of a and b are 1/2 the long axis and 1/2 the short axis, respectively (Figure 4.21).

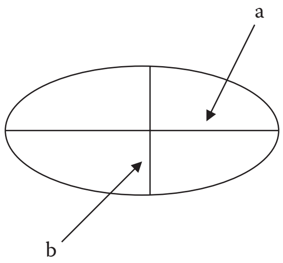


Figure 4.21 Distorted bullet base measurements.

A reasonable approximation of caliber for flattened (oval-shaped) bullets/bullet fragments may be calculated from the long and short axes of the bases. Jacketed bullets tend to yield results closer to the actual caliber than nonjacketed bullets. In any event, it must be remembered that the measured value obtained is an approximation only and should be treated as such.

In a recent shooting incident reconstructed by the author, there was a question as to the number of shooters. A fired .40 S&W cartridge case, a flattened full metal jacketed bullet, and a distorted lead bullet fragment were found at the scene. No weapons were recovered, and the victim had a through-and-through head shot. According to the autopsy report, the entry wound into the victim's head was circular and had a diameter of 0.25 inch. Examination of the bullet and bullet fragment revealed intact bases with an irregular contour for the lead fragment and an oval-shaped base for the jacketed bullet. Measurements were taken of the long and short axes of the bases of the bullet and the bullet fragment. A "best fit" oval was approximated for the lead fragment. Calculations yielded .36 caliber for the lead fragment and .40 caliber for the jacketed bullet. Based on the autopsy report, neither of these projectiles could have been responsible for the 0.25-inch entry wound. The jacketed bullet was consistent with the .40 S&W cartridge case found at the scene. The lead fragment was suggestive of .38 Special/.357 Magnum ammunition. Thus, three different weapons were suggested by the ammunition components and the victim's entrance wound diameter.

There are other calculations associated with shooting incident reconstruction. The bulk of these are associated with exterior ballistics. The calculations are accomplished using ballistics software and will be discussed in Chapter 15.

Problems

1. A bullet hole is located in the aluminum siding of a mobile home. Measurements of the hole reveal a length of 0.63 inch and a width of 0.22 inch. What is the approximate angle of impact for the shot?
   Answer: 20°.
   Solution:

$$\text{Sin impact angle} = \text{width/length} = 0.22/0.63 = 0.3492$$

$$\text{Impact angle} = \text{inverse (arc) sin } 0.3492 = 20.4°$$

2. A shotgun blast into a vehicle door leaves an oblong pattern of nine holes. The overall pattern has a width of approximately 12 inches and a length of approximately 19 inches. What is the approximate angle of impact for the shot?

   Answer: 39°.

   Solution:

$$\text{Sin impact angle} = \text{width/length} = 12/19 = 0.6316$$

$$\text{Impact angle} = \text{inverse (arc) sin } 0.6316 = 39.2°$$

3. It is desired to determine the height of a streetlight at the scene of a shooting incident. A tripod is set up as a point of reference. The tripod center is 30 feet from the base of the streetlight. The tripod is 42 inches high. An angle gauge is used to determine the upward angle from the plane of the top of the tripod to the top of the streetlight. This angle is 67° (Figure 4.22). How tall is the streetlight?

   Answer: 27.6 feet + 42 inches (3.5 feet) = 31.1 feet

   Solution:

$$\begin{aligned}
&\text{in } 67 = X/30\\
&\quad X = 30(\text{Sin } 67)\\
&\quad X = 30(0.92)\\
&\quad X = 27.6 \text{ feet}\\
&\text{Total Height} = 27.6 \text{ feet} + 42 \text{ inches } (3.5 \text{ feet}) = 31.1 \text{ fe}
\end{aligned}$$

4. A series of vehicle shootings takes place along a freeway. A suspect is arrested after having been seen near a water tower in the area. One of the vehicles has a bullet hole through the driver’s door that is 36 inches above the ground. The angle of impact of the bullet is determined to be 70° from the plane of the side of the vehicle downward. The tower is 100 feet tall. The field of view of the freeway from the top of the tower is 300 feet (Figure 4.23). Could the shot have been fired from the top of the tower?

   Hint: The question here is could a bullet originate from the top of the tower and hit the car at an angle of 70° from within the 300-feet field of view?

   Answer: The shot would be possible (Figure 4.24).

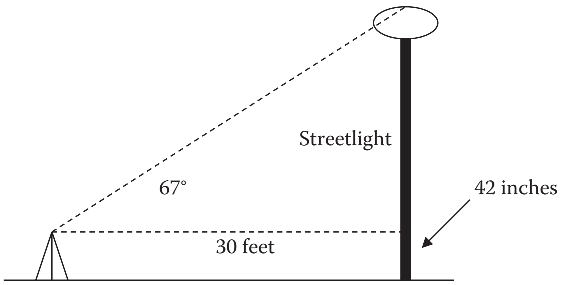


Figure 4.22 Determining the height of a streetlight.

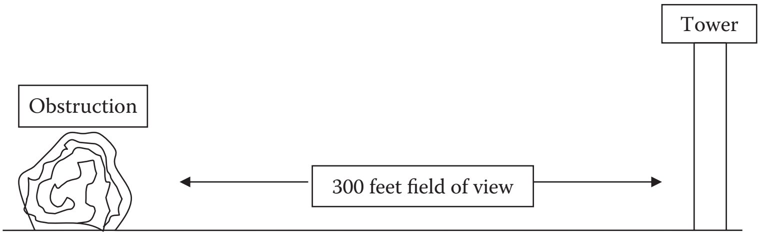
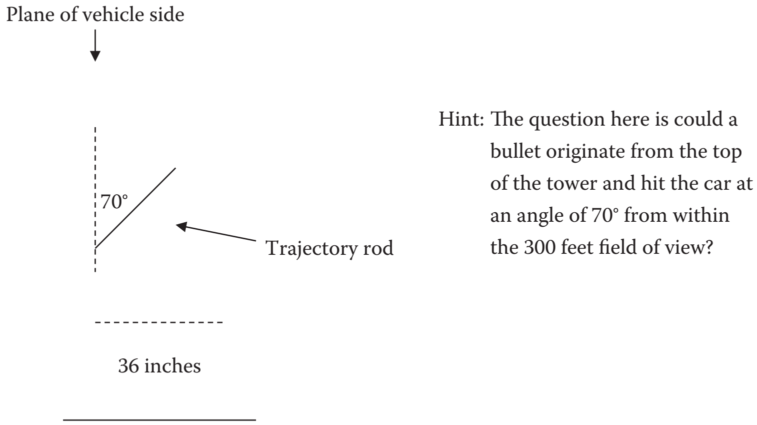

Tower
Obstruction
300 feet field of view

Figure 4.23 Field of view (300 feet) of the freeway from the top of the tower.


Plane of vehicle side
70°
Trajectory rod
36 inches

Hint: The question here is could a bullet originate from the top of the tower and hit the car at an angle of 70° from within the 300 feet field of view?

Figure 4.24 Determining if a bullet fired from the top of the tower could hit a car at an angle of 70° from within 300 feet field of view.

Solution: An imaginary right triangle is constructed with the length of the base being unknown. In order for the shot to be possible, the base length must be less than or equal to 300 feet (to be within the field of view). The height of the triangle is 100 feet minus the height above the ground of the bullet hole (assuming a level terrain) or 97 feet (Figure 4.25).

$$\begin{aligned} \text{an } 70^\circ &= X/97 \\ X &= \text{Tan } 70(97) \\ X &= 2.74(97) = 266 \text{ feet} \end{aligned}$$

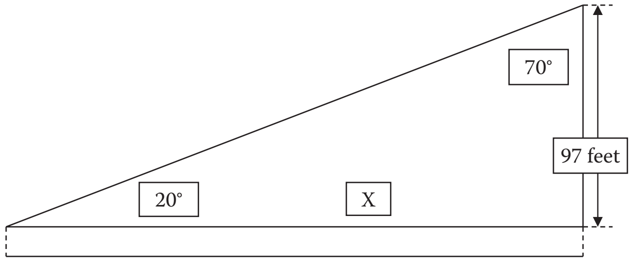

70°
97 feet
20°
X

Figure 4.25 Imaginary right triangle showing base with unknown length.

5. An officer jumps into the bed of a pickup truck just as the driver starts to flee after having been stopped for driving erratically. After repeatedly banging on the roof of the cab with his baton, the officer breaks out the rear glass of the pickup. He then strikes the driver with the baton through the broken window. Still unable to get the driver to stop the vehicle, the officer shoots the driver twice in the back. According to statements made by the officer to investigators after the shooting, the vehicle was moving forward at a high rate of speed when he fired the first shot. The officer stated that he waited "several seconds" and fired a second round after the first shot failed to get the driver to bring the vehicle to a stop. Two fired cartridge cases were found on the grass median next to the curb. The two cartridge cases were resting alongside each other at a distance of approximately 19 feet from the back of the pickup as it sat in the street. A civil suit was ultimately filed by the family of the deceased alleging that the officer shot the man after the man had stopped the pickup and tried to flee on foot. In order to determine the validity of the officer's version of events, cartridge case ejection pattern testing was carried out on his weapon. It was found that, on the average, fired cartridge cases were ejected 19 feet to the right rear of the weapon (Figure 4.26). What do the positions of the fired cartridge cases tell you about how the shooting probably occurred?

   Solution: In order to determine the significance, if any, of the cartridge case locations, we need additional information. The approximate speed of the vehicle at the time the shots were fired is critical here. Additionally, the grade of the street must be considered.

   A reenactment was carried out, and it was determined that the maximum speed of the vehicle at the point at which the shots were fired would be approximately

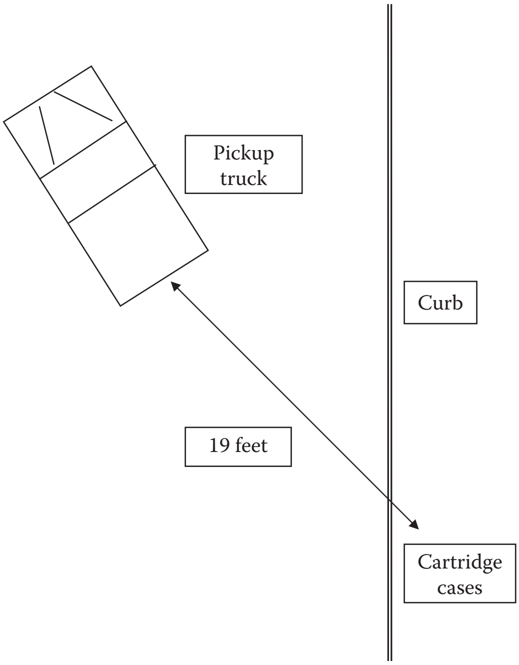


Figure 4.26 Location and distance (19 feet) of fired cartridge cases in relation to the pickup.

25 mph. This was based on the fact that there was a sharp turn that had to be negotiated just before reaching the area of the shooting. There was an incline to the street, meaning the fired cartridge cases would have had a tendency to bounce/roll after landing. The fact that they ended up on the grass could simply be the result of having bounced there after striking the pavement. On the other hand, it is conceivable that they could have landed there directly from having been ejected from the officer's weapon. What must be considered here is the fact that if the officer was firing as the vehicle was moving forward at 25 mph, the cartridge cases would have a forward velocity component of 25 mph as well. By virtue of the rearward ejection paths of the fired cartridge cases, they would have a rearward velocity component. The rearward velocity component can be approximated by determining the average time of flight and average distance of the ejected cartridge cases (Figure 4.27).

Using an average ejection angle of 23° and an average ejection distance of 19 feet, we can calculate the average distance to the rear.

$$\text{Sin } 23° = X/19$$
$$0.3907 = X/19$$

Rearranging and solving for *X*

$$X = 0.3907 \times 19 = 7.42 \text{ feet}$$

We must use the average time of flight for the ejected cartridge cases to determine the rearward velocity component. This average time of flight is determined to be 1 s.

7.42 feet in 1 s gives us a rearward velocity of 7.42 feet/second. The forward component of 25 mph must be converted to feet/second.

$$25 \text{ mph} \times 5280 \text{ feet/mile} \times 1 \text{ hour/60 minutes} \times 1 \text{ minute/60 seconds} = 36 \text{ feet/second}$$

The net velocity for the cartridge case would be the difference between the forward component and the rearward component.

$$\text{Net velocity} = \text{Forward velocity} - \text{Rearward velocity}$$

$$\text{Net velocity} = 36 - 7.42 = 28.58 \text{ feet/second}$$

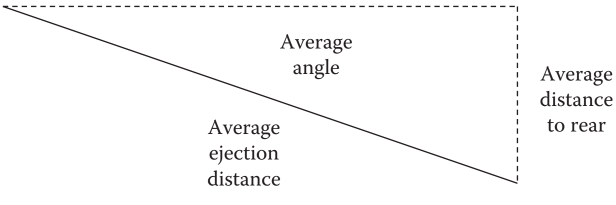


Figure 4.27 Calculating the average distance to the rear using average ejection angle (23°) and average ejection distance (19 feet).

This means that if the shots were fired from the bed of the truck as it was moving forward, the ejected cartridge cases would land forward of their location if fired from a stationary position. Because the cartridge cases were found beside each other and about 19 feet from the bed of the truck and because ejected cartridge cases were found to land about 19 feet away, it appears possible that the shots were fired after the vehicle had come to a stop. On the other hand, if the shots were fired as the vehicle started around the corner, they could have landed in the grass where they were found. Thus, we are unable to answer the question as to whether the shots were fired as the vehicle was moving or after it had stopped. Finding the two cartridge cases together rather than some distance apart appears to refute the officer's account of the shooting. However, the first shot could have taken place as the vehicle started around the corner and the second after it started up the hill with the second ejected cartridge case bouncing/rolling down the hill and landing next to the first one.

Suggested Readings

Barr, D., Modification to the Common Trigonometric Method of Bullet Impact Angle Determination, *AFTE Journal*, Vol. 33, No. 2, Spring 2001, pp. 116–121.

Barr, D., The Trig-Elliptical Method of Bullet Impact Angle Determination, *AFTE Journal*, Vol. 33, No. 2, Spring 2001, pp. 122–124.

Cashman, P.J., Projectile Entry Angle Determination, *Journal of Forensic Sciences, JFSCA*, Vol. 31, No. 1, Jan. 1986, pp. 86–91.

French, M.L., Impact Angle Determination through Plastic Windows, *AFTE Journal*, Vol. 29, No. 1, Winter 1997, pp. 73–79.

Warren, G., Simple Measurement of Angles of Elevation, *AFTE Journal*, Vol. 23, No. 3, July 1991, p. 869.

Firearms and Ammunition Components

5

Firearms come in a vast array of types, styles, designs, and intended uses (e.g., hunting, target shooting, home defense, police, and military). Likewise, ammunition varies significantly as to its design and intended purpose. In order to be able to reconstruct a shooting incident, it is extremely helpful to have at least a working knowledge of various types of firearms and ammunition components. This chapter provides a basic overview of the topic. This information, at a minimum, should be well understood by anyone having any part in the analysis and reconstruction of a shooting incident. The additional pursuit of information relating to firearms and ammunition can only add to the investigator's ability to decipher the information present at a shooting scene and to put it into proper perspective. It is also essential that one stays current as new innovations in firearms and ammunition are introduced. Although firearms and self-contained cartridges have been around for decades, to imagine that there is "nothing new under the sun" when it comes to these components is naïve to say the least.

Firearms Categories and Nomenclature

This section is not intended to be an in-depth study of firearms designs and function, but is offered as a review of some of the fundamentals having direct application to shooting reconstruction. The reader is encouraged to seek out some of the many excellent references on the topic for more in-depth information. A ready source of information may be found on the Internet, particularly at the various manufacturers' websites. Manufacturers typically post operators' manuals for various weapons that can be very helpful in understanding how a particular weapon functions. Ammunition companies typically post images and ballistic data that can assist in identifying fired bullets and cartridge cases as to source and performance.

Firearms (i.e., small arms) may be broken down into two broad categories: handguns and long guns. Handguns are weapons designed to be held in and fired from the hand. Long guns are designed to be fired from the shoulder. There are, of course, all sorts of exceptions to these two categories. For example, there are weapons designed to be fired primarily from waist level while being gripped with both hands, and there are handguns that have detachable stocks that allow them to be fired from either the hand or the shoulder. Nevertheless, this broad classification is sufficient for our current purpose. A few examples are shown in Figures 5.1 through 5.4.

Handguns include pistols, revolvers, and single-shot weapons such as derringers. Derringers frequently have two barrels, so the term "single shot" is really incorrect in that the weapon can actually fire two shots total (Figures 5.5 and 5.6). The term "pistol" typically refers to a handgun having a magazine as opposed to a revolver, which has a cylinder for holding cartridges.

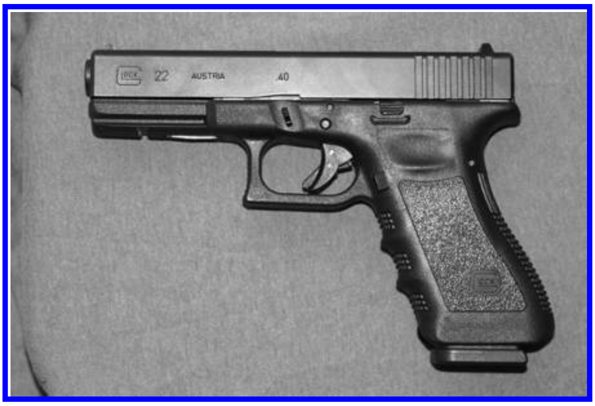


Figure 5.1 .40 cal Glock model 22.

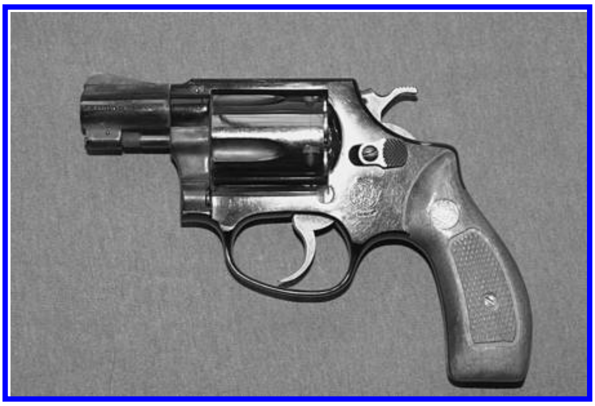


Figure 5.2 .38 cal revolver.

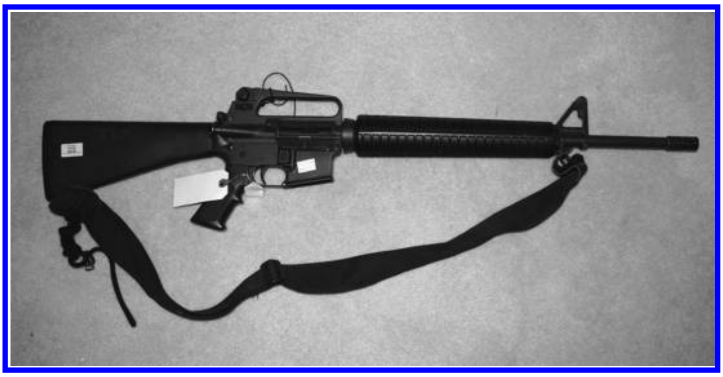


Figure 5.3 Colt AR-15 .223 cal semi-auto rifle.

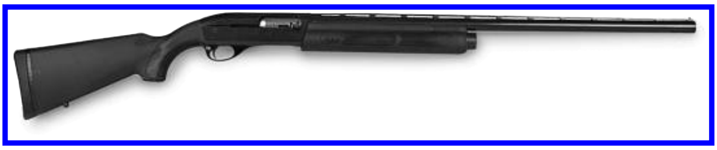


Figure 5.4 12 ga. semi-auto shotgun.

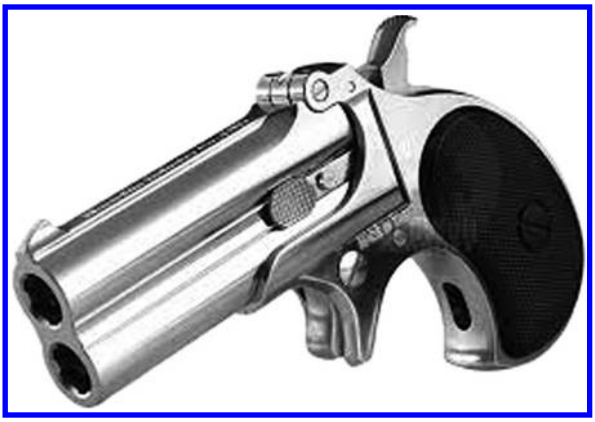


Figure 5.5 Classic .38 cal derringer.

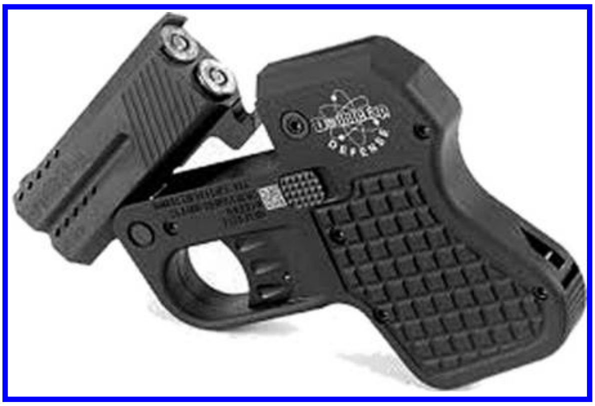


Figure 5.6 Modern .38 cal derringer.

Pistol and revolver actions may be broken down into the categories of single action and double action. Single-action weapons require cocking before pulling the trigger in order to fire. Double-action weapons are cocked as the trigger is being pulled, hence the term double action. Two types of revolvers are illustrated in Figures 5.7 and 5.8.

Semiautomatic weapons are perhaps better described as autoloading. After the initial shot is fired, they reload themselves as a result of the recoil/gases produced forcing the

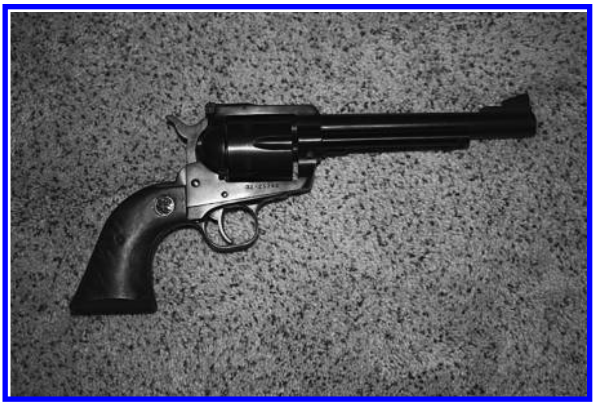


Figure 5.7 Ruger .357 magnum single-action revolver.

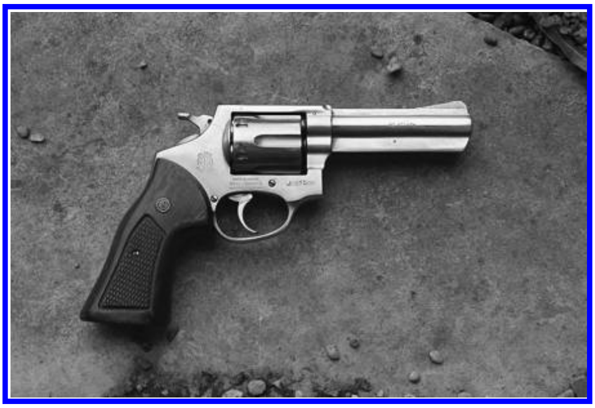


Figure 5.8 Taurus .38 cal double-action revolver.

breech bolt rearward, ejecting the fired cartridge case, then moving forward, stripping a live round from the magazine, seating it in the chamber, and recocking the hammer in the process. The lever action and slide action ("pump") are among the various other type of actions that perform the same functions but are manually actuated without relying on recoil or combustion gases to perform. Figures 5.9 through 5.11 illustrate examples of firearms with these actions.

Fully automatic weapons are generally classified as machine guns or submachine guns. The distinction between the two is simply that machine guns are chambered for rifle ammunition, such as .308 caliber, and submachine guns are chambered to fire pistol ammunition, such as 9 mm. Examples are shown in Figures 5.12 through 5.14.

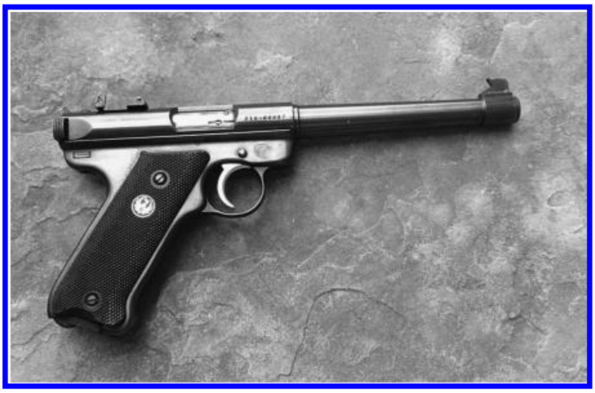


Figure 5.9 Ruger .22 cal semi-auto pistol.

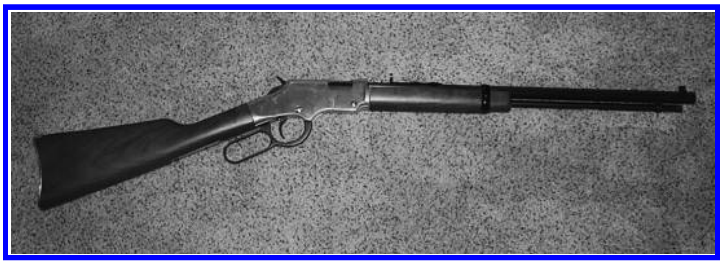


Figure 5.10 Henry .22 cal lever action rifle.

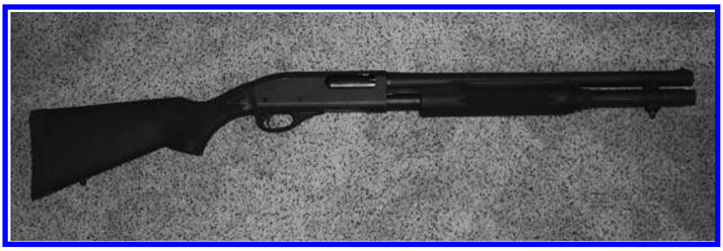


Figure 5.11 Remington 12 ga. pump shotgun.

Early handguns and long guns were produced with smooth bore barrels designed to fire lead balls of various diameters. With the advent of rifled barrels during the mid-1800s came great improvement in the accuracy of the weapons. The rifling allowed the firing of conical-shaped bullets or "miniballs" (as shown in Figure 5.15). The rifling produces spin stabilization of the bullet in flight.

Rifling may be described as a series of helical grooves in the inner surface of a gun barrel with either a right twist or left twist direction. The raised areas between the grooves

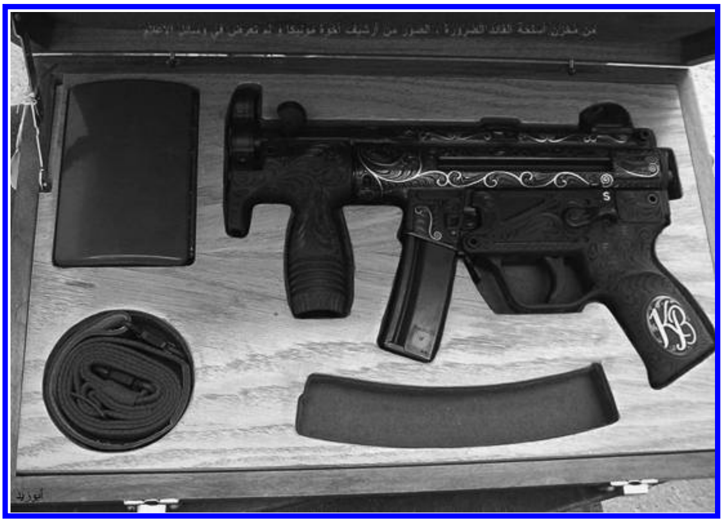


Figure 5.12 Custom 9 mm submachine gun seized by U.S. forces in Iraq.

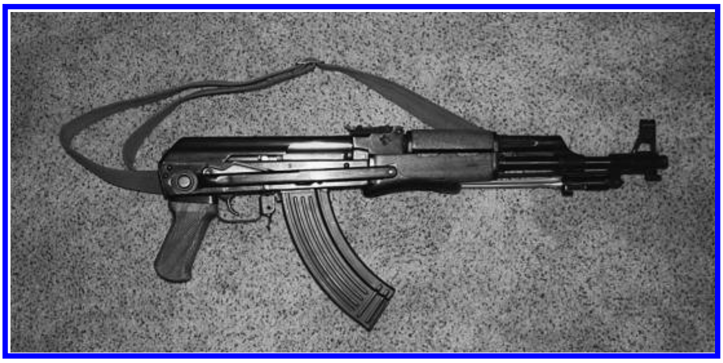


Figure 5.13 AK-47 machine gun (7.62 × 39 mm).

من مخزن أسلحة القائد الضرورة، رشاشات ذهبية و بلاتينية لم تستعمل. الصورة من أرشيف أخوة مونيكا- و غير منشورة سابقا
أبوزيد

Figure 5.14 Custom gold and silver plated AK-47 machine guns seized by U.S. forces in Iraq.

are known as lands. The rifling process is carried out using a variety of techniques. The two basic categories of rifling are cut rifling and hammer forged (polygonal) rifling. With cut rifling, a cutting device of one design or another is used to create the helical grooves. Polygonal rifling is created through the use of a mandrel that is inserted into the barrel and hammered to form the rifling.

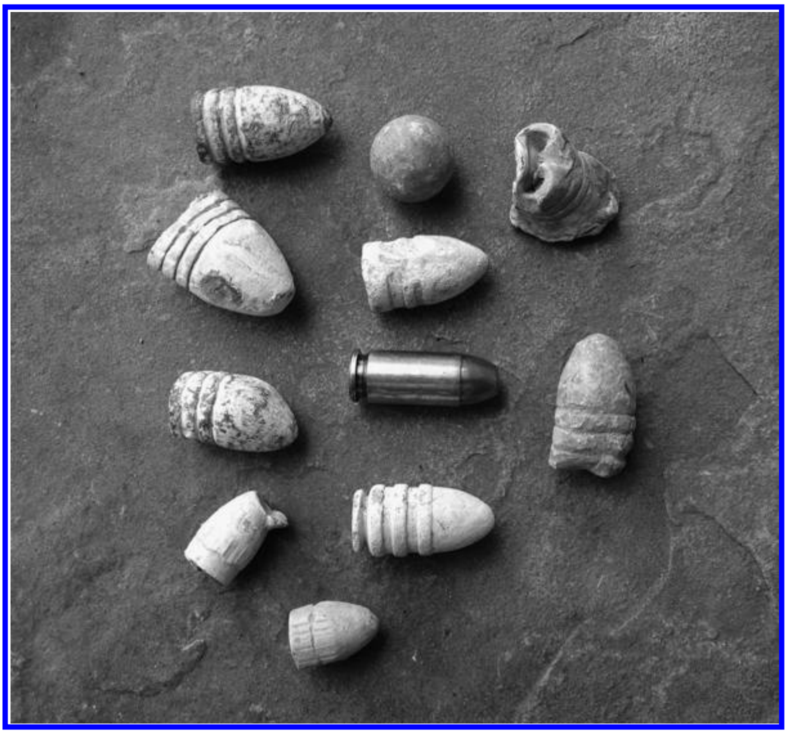


Figure 5.15 Civil War miniballs (modern .40 cal round at center).

Traditional cut rifling and polygonal rifling are distinguishable by the squared-off edges of the grooves/lands on cut rifling as opposed to rounded edges for polygonal rifling. Many modern police weapons, such as Glock and Heckler & Koch, have polygonal rifling, whereas Sig Sauer, Kimber, and others have traditional cut rifling. Although this is of primary interest to the firearm examiner, the field investigator should be able to recognize the type rifling present in a gun barrel by simply looking at the muzzle end of the barrel. Examples are shown in Figures 5.16 through 5.18.

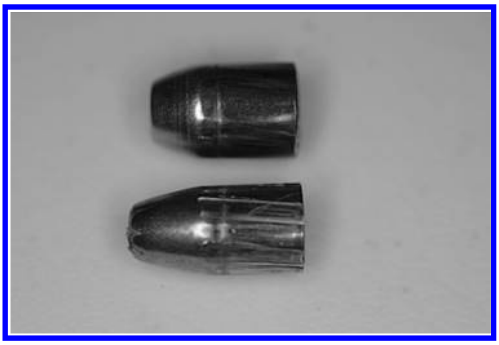


Figure 5.16 Cut (bottom) versus polygonal rifling (top).

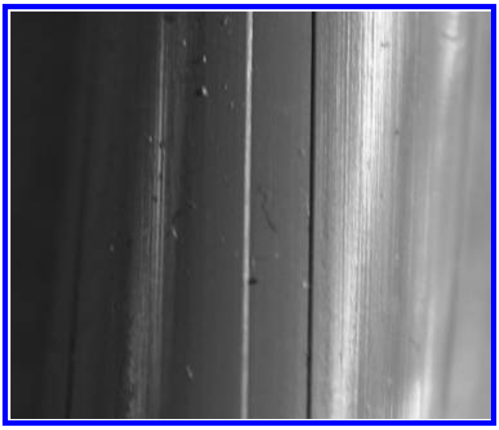


Figure 5.17 Cast of barrel with cut rifling (left twist).

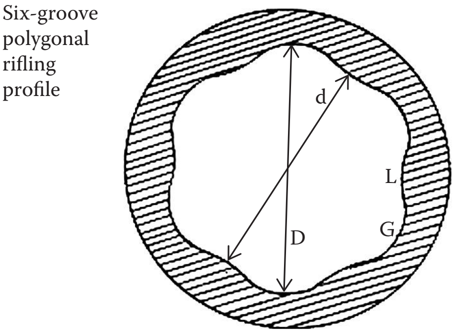


Figure 5.18 Polygonal rifling.

By being able to establish the rifling type (i.e., cut or polygonal) and determining the number of lands and grooves and the direction of twist at the scene, the investigator may make preliminary determinations (to be confirmed by a firearm examiner in a crime laboratory later). The reason for this is that there will frequently be fired bullets found at shooting scenes along with suspect weapons. Rather than having to wait for the evidence to be examined by the firearms unit and then wait to receive the report of findings days or weeks later, it is of investigative value to be able to make a determination at the scene as to the possibility or impossibility of a bullet having been fired from a weapon. Ultimately, it is essential that the items be submitted to the firearms unit of a crime laboratory for confirmation of any hypotheses developed by field investigators.

To determine the general rifling characteristics of a bullet, one simply needs to hold the bullet parallel to the ground and look straight down at it. If the rifling cants to the left when viewed in this manner, it has left twist and vice versa if it cants to the right. As it turns out, most gun barrels have a right-hand twist to their rifling. A common exception would be a Colt 1911 pistol, which has a left-hand twist. There is no inherent advantage of right-hand twist over left-hand twist, and the proliferation of right-hand twist barrels might be categorized as simply being because "it is a right-hand world."

Next, the number of lands/grooves is determined by counting as the bullet is rotated. This is shown in Figure 5.19. This can be somewhat difficult to do with damaged and/or poorly defined rifling. Certainly, if the bullet is bloody or has other trace evidence adhering, this type of handling/examination may have to be reserved for the firearms unit and not attempted at the scene.

The general rifling characteristics of a gun barrel are fairly easily determined by looking into the muzzle of the weapon. It should go without saying that the gun must have

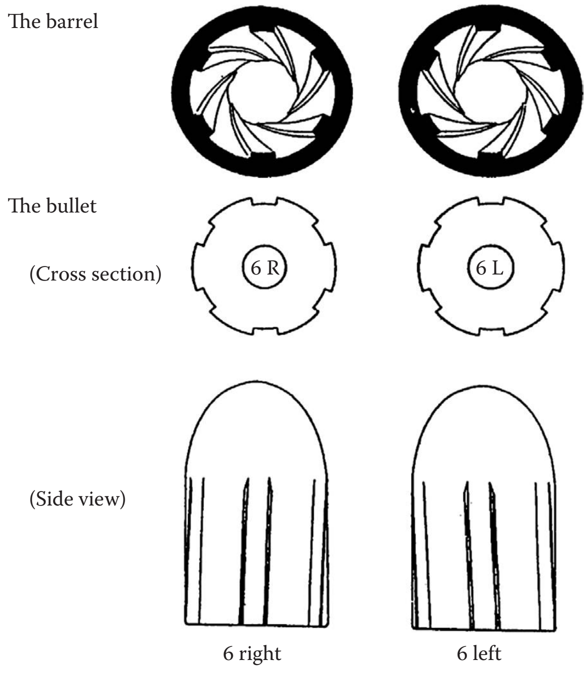


Figure 5.19 General rifling characteristics.

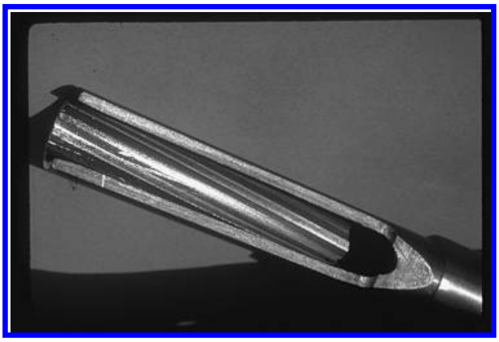


Figure 5.20 Cutaway of barrel with left twist.

first been photographed in place, made safe (i.e., unloaded and the loading status properly documented) and that trace evidence considerations (latent prints, hairs, fibers, blood, etc.) have been addressed before picking up and handling the gun. If one looks into the muzzle of a barrel at an oblique angle (less than 90°), it is usually possible to see and count the number of lands/grooves. By looking down at the muzzle from the top of the barrel, the direction of twist can be determined by noting if the rifling cants to the right or left. This can be seen in Figure 5.20.

In this way, a field investigator can quickly and easily include or exclude a weapon as having fired a bullet when the circumstances permit and there is urgency from an investigative standpoint. Again, the evidence would ultimately be submitted to the firearms unit for complete examination and confirmation of the preliminary observations as previously stated.

An investigator arrives at a crime scene to find a body lying on the floor inside a residence, the apparent victim of a gunshot wound to the head. There is a snub-nose .38 caliber revolver lying next to the body. Further examination of the scene results in the location of a fired bullet on the floor just under the skirt of a sofa in the same room.

Once the scene has been properly documented by measuring evidence locations, incorporating them into a sketch of the scene, taking appropriate photographs, and videotaping the scene, the investigator prepares to collect the evidence. As the bullet is collected, the investigator observes that it bears eight lands and grooves with a right twist direction. Upon carefully picking up the revolver (while wearing unused gloves) so as to avoid touching any smooth areas likely to have latent prints/DNA, the investigator uses a scribe to score a line onto the cylinder on both sides of the top strap. Once this is done, the investigator carefully opens the cylinder latch and swings out the cylinder. The contents of each chamber in the cylinder are recorded and the items removed and placed into containers for submission to the crime laboratory. Continuing to handle the weapon so as not to obliterate/damage possible latent prints or compromise DNA testing, the investigator looks into the muzzle of the revolver and determines that it has cut rifling and there are six lands and grooves. By looking from above the front sight down to the bottom edge of the muzzle, the investigator is able to tell that the rifling cants to the left.

It is clear from the investigator's examination of the bullet (eight lands/grooves with a right twist) and the revolver (six lands/grooves with a left twist) that the bullet found at the scene could not have been fired from the revolver. Does this mean that the victim was shot with another gun? Not necessarily, because it must first be established that the victim has a perforating wound to the head (through and through) and that the bullet found is consistent with the bullet holes in the skull. If it turns out that there is no exit hole in the victim's skull, then it would be expected that a bullet would be recovered at autopsy. In which case, the firearm examiner would have to compare the bullet found at the scene with the autopsy bullet to determine if only one gun was involved or not.

In any event, it is important for the investigator to know that the revolver and the bullet found at the scene are not related, and it is most important to know this while still at the scene. In this way, the investigator can immediately begin to consider other scenarios and look for corroborating evidence. This can help avoid one of the pitfalls of having many years of experience and "having seen this many times before": a rush to judgment. It is not uncommon, when there are no obvious contradictions, to make an assessment as to the type of event on the basis of the general appearances only. This seems to happen most frequently in cases where suicide appears to be a consideration.

An investigator at a police shooting notes that the suspect was firing a Smith & Wesson semiautomatic pistol with traditional cut rifling, whereas the officer's duty weapon is a Glock with polygonal rifling (both are .40 caliber and both have right twist). There are several fired bullets at the scene. The investigator is easily able to distinguish bullets fired by the officer from those fired by the suspect based on the visible difference in polygonal versus cut rifling. His notes and subsequent report will be worded "apparent" polygonal rifling subject to confirmation by the firearm examiner.

When a revolver is fired, there is going to be a deposition of soot on the cylinder face around the chamber involved. This is particularly evident if the weapon was clean before the firing, but it is still usually recognizable even on dirty weapons. These deposits are known as halos or cylinder flares. This is illustrated in Figure 5.21. Note that the last chamber to have been fired should have a cylinder flare that overlaps those on either side (the middle chamber of the three on the right side shown).

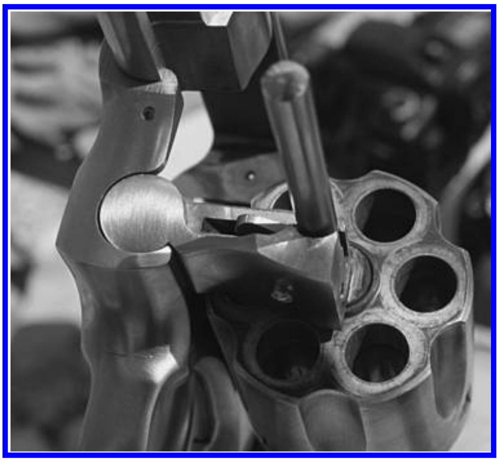


Figure 5.21 Cylinder halo (middle chamber was fired last).

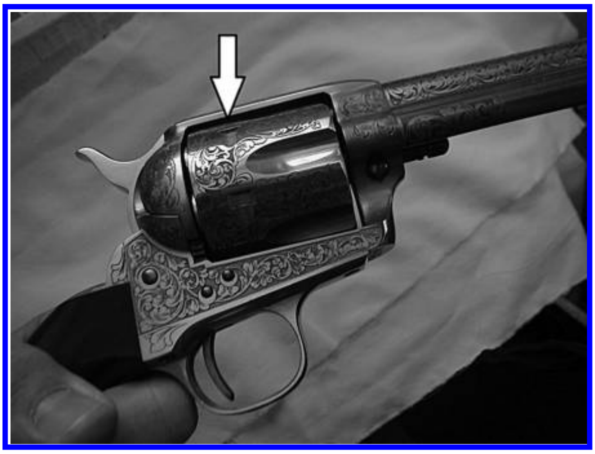


Figure 5.22 Cylinder notch.

The cylinder of a revolver can rotate clockwise or counterclockwise (as viewed from the back of the weapon). The rotation direction can easily be determined by merely noting the shape of the notches in the side of the cylinder rather than by having to work the action. This is especially helpful when multiple shots have been fired from a revolver and different brands of ammunition were used. The cylinder notches are typically in what is suggestive of an arrowhead shape. The "point" of the arrowhead shows the direction of rotation of the cylinder. This can be seen in Figure 5.22.

By combining the cylinder flare information with the cylinder rotation direction and the loading status of a revolver, it can frequently be determined what the sequence of shots was and whether the cylinder was opened and the weapon reloaded during a shooting. Similarly, the staging of a shooting incident can sometimes be ascertained through examination of these characteristics.

A revolver is recovered from a suspect after a shooting outside a police station at shift change. The suspect was reportedly disgruntled over having received multiple traffic citations from different officers within the same day and had decided to vent his frustrations by waiting in the police station parking lot for officers arriving and departing at shift change time. Two officers were subsequently shot by the suspect before he could be wrestled to the ground and disarmed.

The two bullets recovered from the wounded officers were different in design. One was a hollow point, and the other was a blunt nose (see Figure 5.23).

When the revolver was examined, the investigator noted that the cylinder notches indicated that the revolver cylinder rotated clockwise. After marking the location of the cylinder by making a mark on each side of the top strap, the investigator opened the cylinder and observed a fired Winchester cartridge case to have been under the hammer and a fired Federal cartridge case to be in the chamber immediately to the right. A visual check of the cylinder face revealed that the chamber with the Winchester cartridge case had a cylinder flare that overlapped the ones on either side. It was further observed that the chamber with the Federal cartridge case had what appeared to be a recent cylinder flare as well. Once the cylinder contents were recorded and the contents removed and packaged as evidence, the investigator also noted that there were powder particles and soot residue inside the two chambers as well.

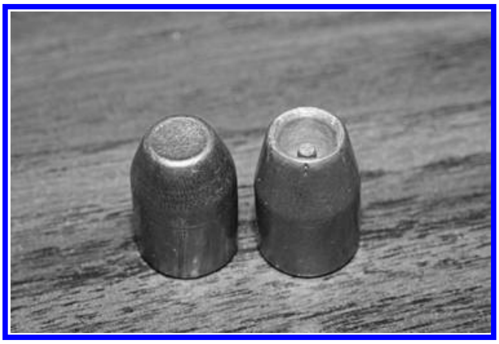


Figure 5.23 A blunt nose Winchester (left), and a hollow point Federal (right).

It was evident to the investigator, by having examined the revolver, that only two shots had been fired and that the cylinder position had not been changed after the second shot. It also appeared to the investigator that there was a good chance that the firearm examiner would be able to determine which one of the officers had been shot first. In the midst of the shooting, no one had really been sure which officer was hit first.

After examining the weapon, the fired cartridge cases, and the bullets, the firearm examiner had been able to conclude that the suspect's revolver did, in fact, fire the two bullets that struck the officers. The bullet with the scalloped jacket was identified as being consistent with Federal ammunition and the other bullet with Winchester ammunition. The firearm examiner noted that, based on cylinder flares and cylinder rotation direction, the Federal round would have been fired first. Thus, the firearm examiner confirmed the field investigator's belief that the sequence of shots could be ascertained from the weapon condition and the ammunition evidence.

Special Notes Concerning Firearms

The following summary notes constitute useful things to keep in mind during the course of evaluating a shooting scene and/or in the reconstruction of a shooting incident.

Random Notes about Handguns

- Both revolvers and autoloading pistols may be single-action or double-action.
- The trigger pull for double-action handguns is typically about 12–15 pounds.
- The trigger pull for single-action handguns is typically about 3–10 pounds.
- Half-cock is not a "safe" position on a single-action handgun.
- Cylinder rotation direction may often be ascertained by observing the cylinder notches.
- Hammer block and transfer bar safety mechanisms are very reliable and seldom fail.
- Nearly all semiautomatic pistols have at least one manually operated safety device.
- Semiautomatic pistols are typically either blowback or recoil operated.
- Cartridge case ejection patterns vary for automatic pistols and for different loads.
- Older handguns often have identifying grip marks (i.e., logos/trademarks).
- "Silencers" are ineffective on revolvers because of the cylinder gap.

- Subcaliber devices and barrel adapters allow large caliber handguns to fire smaller caliber bullets (e.g., .22 caliber in a 9-mm barrel).
- Pellets may be fired in handguns using special shot shells (e.g., rat shot) (Figure 5.24).
- If the slide of a semiautomatic pistol is moved back slightly, the pistol will typically not fire owing to becoming "out of battery."
- There are pistols that are chambered for rifle cartridges (e.g., FN 5 Seven chambered for 5.7 × 28-mm bottleneck cartridges) (Figure 5.25).
- Rifles that are chambered for pistol cartridges are also available (e.g., Marlin lever action rifle chambered for 44 magnum pistol ammunition).

Note: A number of the preceding details are being mentioned for the first time in this text. It is highly recommended that the reader seek out whatever supplemental information necessary in order to fully understand the noted information. One highly useful website is that of retired firearm examiner Scott Doyle (http://www.firearmsid.com). Otherwise, merely doing a Google search for the topic of interest usually provides good information.

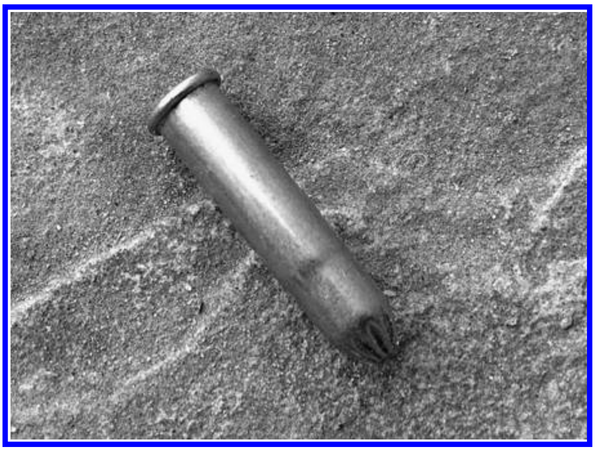


Figure 5.24 .22 cal rat shot.

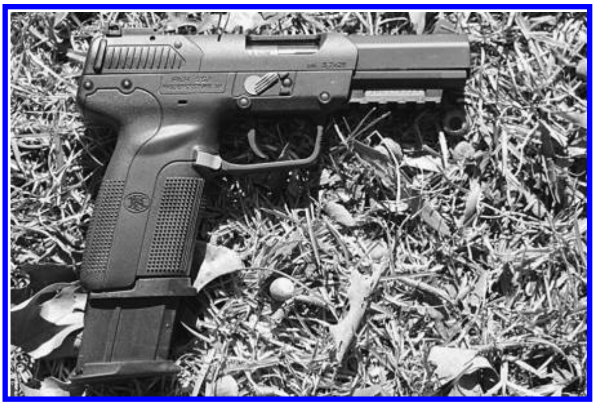


Figure 5.25 FN 5 Seven (5.7 × 28 mm).

Random Notes about Rifles

- Autoloading may be recoil or gas operated.
- Rifles are designed to be fired from the shoulder.
- Federal law requires a 16-inch minimum barrel.
- Variable cartridge case ejection patterns can be found in similar rifles owing to manufacturing deviations (e.g., many AK/SK rifles eject forward, but some eject to the right rear).
- Accelerator rounds allow smaller bullets to be fired in large caliber rifles.
- Subcaliber devices allow the firing of small caliber bullets in larger caliber rifles.
- The "sighted in" range is where a bullet impacts the point of aim (trajectory and line of sight coincide).
- Shots fired uphill or downhill hit higher than the line of sight.
- Things such as wind, temperature, and humidity become major concerns at 500 yards.

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Random Notes about Shotguns

- Duplex loads contain two different size shot, whereas triplex loads contain three.
- One inch of shot spread is approximately equal to 1 yard of muzzle to target distance (for nine pellet 00 buckshot loads *only* fired in full choke barrels).
- Shot cup/wad in wound is an indication of a reasonably close range shot.
- Buffer material may help establish muzzle to target distance.
- Chokes range from no constriction (cylinder bore) to maximum constriction (full choke) with improved cylinder, modified and improved modified in between.
- Rifled slugs may be fired in shotgun barrels.
- Shotguns may have rifled barrels (Hastings Co.) for shooting slugs w/o cast rifling.
- Shotgun gauge is the number of lead shot of the bore diameter required to equal one pound.
- Shot shell lengths are generally 2 3/4 or 3 inches, but exceptions are found in European target and light field loads.
- Most modern shot shells are plastic and are made with a variety of head designs and may or may not have a brass head.
- Standard plastic shot cups may travel 30–40 yards downrange when fired horizontally.
- Shot cups, particularly heavy walled tactical cups, can cause serious injury at close range.

Note: A number of the above details are being mentioned for the first time in this text. It is highly recommended that the reader seek out whatever supplemental information necessary in order to fully understand the information. One highly useful website is that of retired firearm examiner Scott Doyle (http://www.firearmsid.com). Otherwise, merely doing a Google search for the topic of interest usually provides good information.

Random Notes about Submachine and Machine Guns

- Submachine guns fire pistol ammunition.
- Submachine guns can fire from open bolt (e.g., Mac10) or from closed bolt (e.g., H&K).
- Machine guns fire rifle ammunition (e.g., .308 Winchester).
- Distorted cartridge case heads are indicative of open bolt and possibly full automatic fire.
- Select-fire/semiautomatic fire is inherently more accurate than full automatic fire in most situations due to the shooter being able to maintain target (note: this has prompted some police agencies to go to low recoil rounds such as 5.7 × 28).
- Machine guns can be belt-fed (e.g., M-60) or magazine-fed (e.g., AK-47).

Note: A number of the above details are being mentioned for the first time in this text. It is highly recommended that the reader seek out whatever supplemental information necessary in order to fully understand the information. One highly useful website is that of retired firearm examiner Scott Doyle (http://www.firearmsid.com). Otherwise, merely doing a Google search for the topic of interest usually provides good information.

Ammunition Components

As with the previous section, this section is in no way intended to be a complete reference on the subject but is to serve as a review of basic principles. The reader is again encouraged to seek out other references for more complete information. The basic unit of handgun and rifle ammunition is the cartridge. As shown in Figure 5.26, the cartridge consists of a cartridge case, a powder charge, and a bullet. The majority of the general public refers to this entire unit as a "bullet." Thus, it is not uncommon for attorneys to refer to cartridges as bullets at trial and for the jury to think cartridge when the term is used to only designate the projectile portion, as discussed in Chapter 1. It is up to the shooting reconstruction expert to make sure that the term "bullet" is used properly in reports and subsequent testimony and that all interested persons understand what is being referred to. Figure 5.26 thus is a "cartridge" or a "round," not a "bullet."

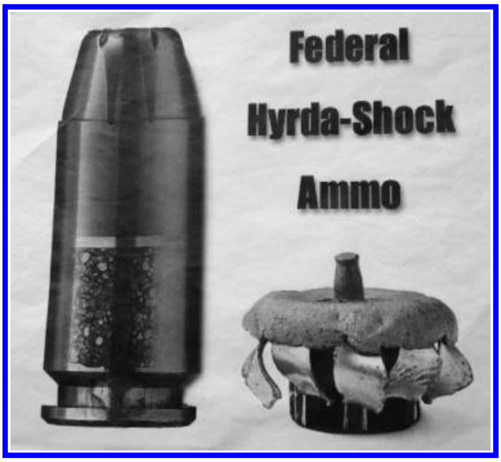


Figure 5.26 Cartridge and fired bullet.

Thanks to the huge number of different bullet designs and configurations, fired bullets recovered from victims and inanimate objects can often be easily distinguished from one another and identified as to manufacturer. Bullets may consist of primarily lead, primarily copper, or have a lead core with a copper jacket or a thin electroplated coating of copper. An example of cartridges with three different bullet designs is shown in Figure 5.27.

Also present in the cartridge case is a priming mixture that consists of a shock-sensitive explosive, such as lead styphnate, that ignites the powder charge following impact by the firing pin/striker. Two basic designs are used for locating the priming mixture in the cartridge case: rim fire and center fire. The rim fire incorporates the priming mixture in the annular rim of the cartridge case base. The .22 caliber cartridge in short, long, and long rifle configurations is the most commonly encountered rim fire cartridge (see Figure 5.28). Other popular rim fire cartridges include .22 Magnum and .17 caliber.

The center fire design has a primer pocket in the cartridge case base that seats the primer. The primer consists of a metal cup that contains the priming mixture. Because rim fire cartridge cases cannot be "reprimed" they are not reloadable, whereas center fire cartridge cases are. Common center fire cartridge case designs are shown in Figure 5.29 along with a rim fire (to the far left). The different designs represent the different types of weapons (e.g., revolvers vs. semiautomatic rifles and pistols) they are designed to be typically fired in.

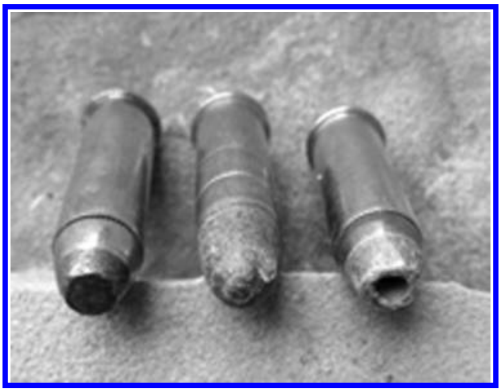


Figure 5.27 (Left to right) Blunt nose, round nose, hollow point.

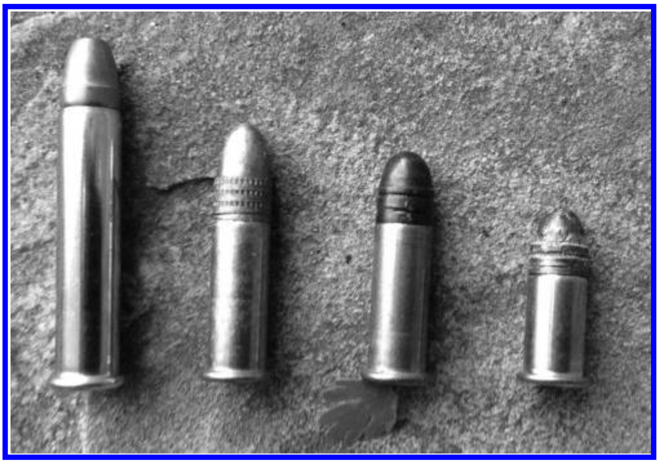


Figure 5.28 (Left to right) 22 Magnum, 22 long rifle, 22 long, 22 short.

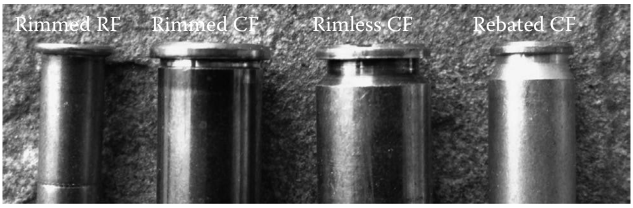


Figure 5.29 Case designs.

The basic unit of shotgun ammunition is the shot shell (or shotgun shell). The shot shell consists of a paper or plastic tube with a brass base. It may also be entirely constructed of plastic. Shot shells are center fire but differ from other cartridges in that they have what is termed a battery cup, which supports the primer cup. Within the shot shell will be found a powder charge and shot pellets. A wad or shot cup separates the shot from the powder charge. The wad may be constructed of paper or plastic. A shot cup is constructed of plastic. The shot is classified as either "bird shot" or "buck shot" depending on the intended target (i.e., birds or deer/large animals). The shot varies in size from number 12 birdshot to 000 buckshot. Refer to Table 5.1 for a comparison of shot sizes.

Shot shells may also have a single projectile called a slug. These various components are shown in Figures 5.30 and 5.31.

Detailed discussions of how these various ammunition components factor into the reconstruction of shooting incidents follow in later chapters.

In the more esoteric arena are devices that allow the firing of a bullet that is smaller than the actual weapon caliber. Of these various devices, the sabot is probably the simplest. A sabot consists of a polymer "cup" that has an outside diameter that is the same as the caliber of the weapon to be used. The sabot fits into the cartridge case in the same manner as the bullet that would be used. The cavity of the sabot accommodates a smaller bullet than the caliber of the weapon. A sabot designed for a .30 caliber weapon so as to be able to fire a .223 caliber bullet is illustrated in Figure 5.32.

The sabot is what the rifling of the barrel gets impressed on upon discharge. The bullet exits the barrel, the sabot separates, and the bullet continues on to its target. The bullet will be devoid of rifling. It would be a rare occurrence indeed to find a sabot at a shooting scene, particularly an outdoor scene where it is usually very difficult to find.

Occasionally, bullets and barrels are not of corresponding dimensions such that one is slightly undersized relative to the other. The result can be a fired bullet with no evidence of

Table 5.1 Shot Comparison Diameters

					Shot Sizes					
Bird shot sizes	12	9	8½	8	7½	6	5	4	2	BB
				Pellet Diameter						
Inches	0.05	0.08	0.085	0.90	0.95	0.11	0.12	0.13	0.15	0.18
Millimeters	1.27	2.30	2.16	2.29	2.40	2.79	3.05	3.30	3.81	4.57
Buck shot sizes	No. 4	No. 3	No. 2	No. 1	No. 0	No. 00	No. 000			
				Pellet Diameter						
Inches	0.24	0.25	0.27	0.30	0.32	0.33	0.36			
Millimeters	6.10	6.35	6.86	7.62	8.13	8.38	9.14			

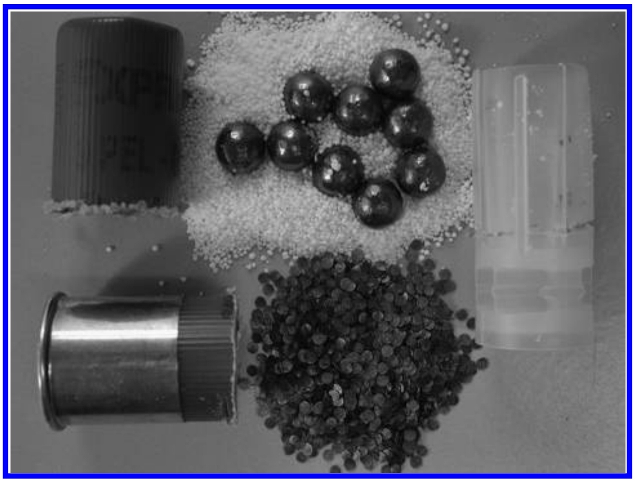


Figure 5.30 Disassembled 00 buckshot shell.

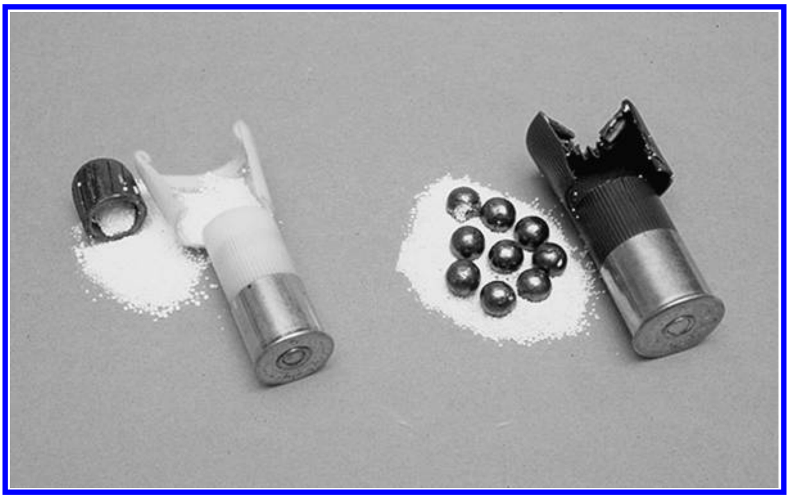


Figure 5.31 Slug, 00 buckshot partially disassembled.

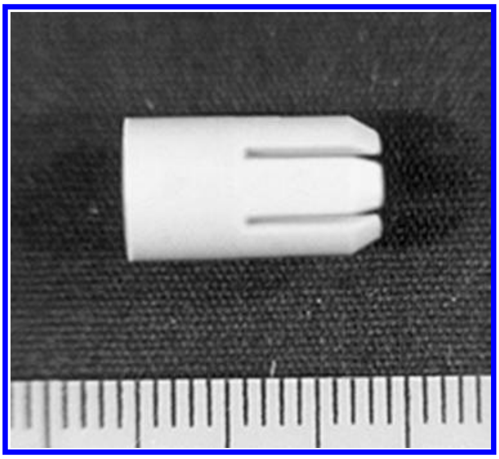


Figure 5.32 Sabot for firing 223 bullet in .30 cal rifle.

rifling impressions even though it has passed through a rifled barrel. The bullet in Figure 5.33 was fired through a Browning Hi-Power 9-mm barrel.

This case involved a through-and-through shot to a German tourist at the Grand Canyon. The bullet exited and was found lodged in a paper container of powdered drink mix. The bullet is a cast lead bullet. A 9-mm Browning Hi-Power pistol was recovered from the suspect, an avid hand loader. Although the use of lead bullets in semiautomatic weapons is generally discouraged, they will work okay if there is enough tin content to make the bullets harder than normal. By being harder, the bullets have fewer problems feeding from the magazine into the chamber.

The suspect's weapon was fired with jacketed ammunition and engraved the bullets as expected. In examining the evidence bullet, it was noted that a lubricating groove was devoid of lubricant. Other similar bullets in the suspect's reloading supplies had blue-colored grease in their grooves. This clearly indicated that the bullet in evidence had actually been fired. Otherwise, grease would still be present in the groove. But why no rifling marks?

In order to answer the question, hand loads were constructed using bullets from the suspect. When these hand loads were fired in the suspect's Browning pistol, the bullets were found to be absent of any rifling just like the evidence bullet. It was time to find out what was going on here! The unfired bullet diameter was determined by measuring with a pair of calipers. The internal barrel cross-sectional diameter was also measured. From these two measurements, it became apparent that the bullets were several thousandths of an inch smaller in diameter than the bore of the barrel. The question was why?

Further investigation revealed that the American bullets worked fine in American-made 9-mm pistols. It was the Browning Hi-Power that was the problem. As it turns out, European 9-mm barrels all have a bore that is slightly oversized compared to American-made weapons. Thus, the cast lead bullets were slipping within the bore and not being engraved with the rifling. Interestingly, the author encountered another case involving a 9-mm Browning Hi-Power and cast lead bullets a few years later. Just as before, the bullet involved bore no rifling marks. This time, however, the answer was already known.

In shooting reconstruction, there are frequently unusual and different situations that will be encountered. The examples that have been presented thus far are only a few of the many unusual aspects of shooting reconstruction that might be encountered. By applying the scientific method, the answers to most of the questions that arise can be found. As unlikely as it might seem, the author saw a second example of the use of hand loads involving lead bullets fired in a Browning 9-mm pistol a few years after the example already cited. The second time around was not a challenge, however.

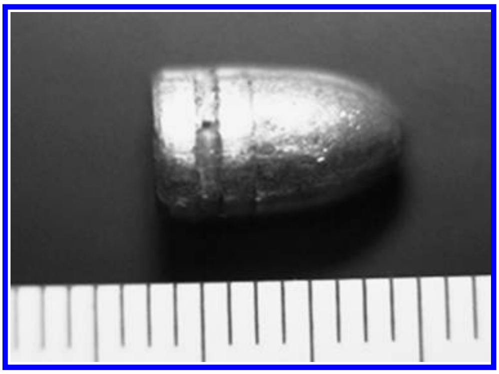


Figure 5.33 9-mm bullet without rifling.

Scene Documentation of Weapons

It is extremely important to properly document the configuration of weapons as they are found at the scene. Proper documentation includes photographs, written notes, and loading diagrams. The written notes are especially important because photographs do not always show the detail of particular interest or they do not turn out at all (a good reason to review digital images at the scene—no surprises!). Consider the weapon shown in Figure 5.34. What would you note about the weapon if you observed it, say, lying on the floor in a shooting scene?

If you observed and noted that the slide safety is off, the hammer is down, and the magazine is fully seated, you are on the right track. These and other similar aspects of weapons may be significant considerations in a shooting reconstruction. In this particular example, the fact that the magazine is fully seated suggests that there may be rounds in the magazine and or the chamber. Because the hammer is down, however, it does not appear that the gun was fired unless the hammer was manually released after firing (if it had been fired and a round was left in the magazine, it would have reloaded and recocked automatically).

What would you note about the configuration of the weapon in Figure 5.35?

The magazine is fully seated, but the only visible external safety is on the front of the trigger. Thus, we cannot determine whether the gun may have been fired based only on

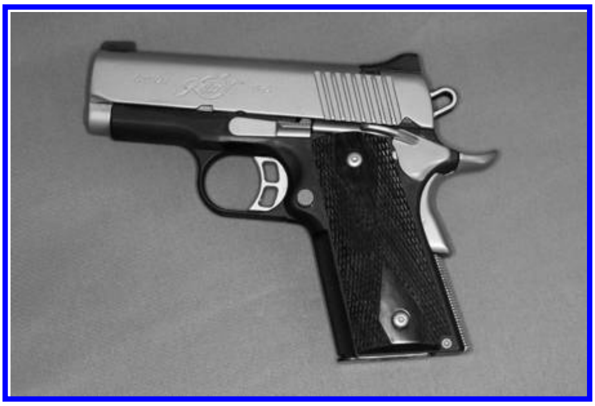


Figure 5.34 .45 cal Kimber.

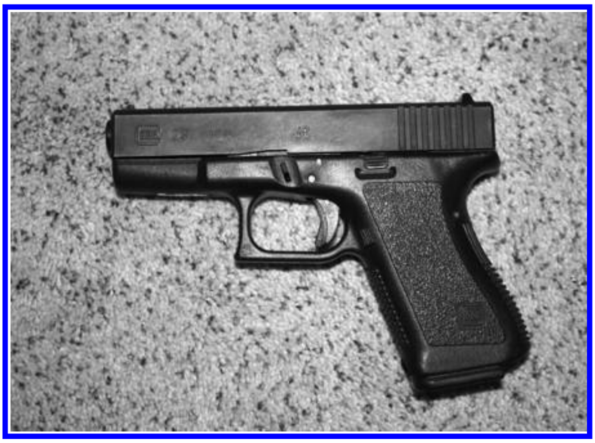


Figure 5.35 .40 cal Glock 23.

what we can see. This type of information may have no real significance with regard to circumstances and events in the shooting. On the other hand, it may be very pertinent. In any event, the pistol needs to first be visually examined and then properly documented.

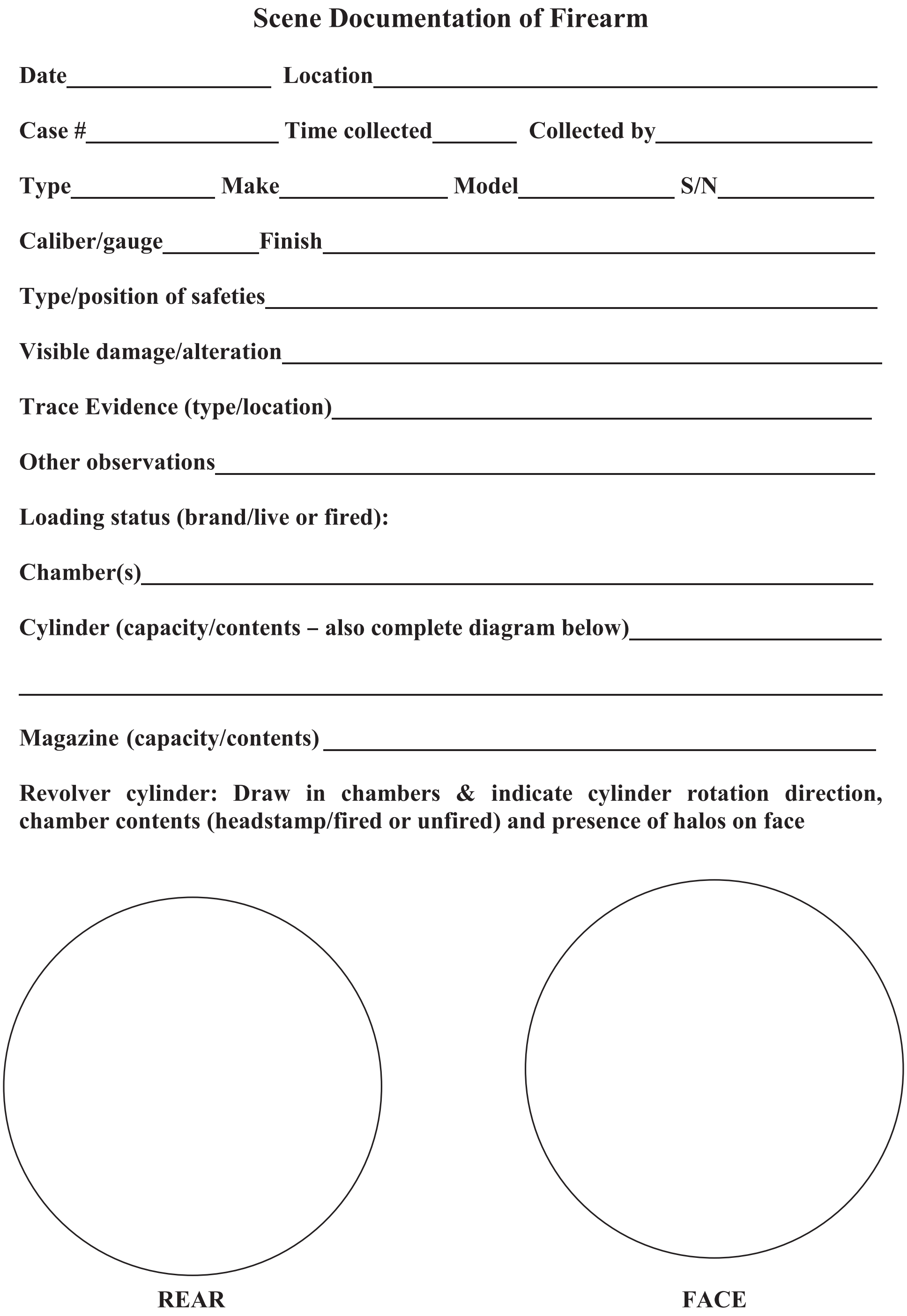
The contents of revolver cylinders and hand gun/long gun magazines need to be recorded. Likewise, the chamber contents need to be documented. It is a good idea to use a standard form that is completed for each weapon at the scene as it is unloaded. As previously discussed, knowing the cylinder rotation and the loading status of a revolver can sometimes allow determination of shooting sequence. A sample loading diagram is shown in Figure 5.36. The position of safeties, decockers, and hammers is to be recorded. The presence of visible trace evidence should also be noted, along with any damage to the weapon.

The loading status of the magazine of a weapon can provide information as to the number of shots fired. This can be compared to the number of fired cartridge cases and bullets recovered. This can be useful in resolving questions as to how many shots were fired by the different persons involved in a shooting incident. This "shot accounting" is an important part of shooting reconstruction, particularly when multiple shooters are involved.

Six officers were involved in a border crossing incident in which a man drove around the barriers at the border crossing to enter the United States from Mexico. As the man drove his vehicle through the crossing, one of the officers fired shots at the vehicle. For some reason, the man turned the vehicle around and began driving back toward Mexico. As he once again sped toward the barriers at the crossing, six officers began firing on his approaching vehicle and continued firing as he sped by them. A rain of bullets failed to hit the driver but struck the vehicle causing it to come to a stop short of the Mexican side of the crossing. The man then jumped out of the vehicle and began to run toward the border. Two more shots rang out, striking him in the back and killing him. A total of 42 fired cartridge cases were found on the roadway at the crossing.

The investigators that were brought in began by collecting weapons from each of the six officers as well as the 42 fired cartridge cases. As many of the fired bullets missed their targets, the fired cartridge cases were the most reliable way to determine the total number of shots fired. The number of shots fired by each officer required firearm examination of the cartridge case markings and comparison to test fires from each officer's weapon. As an additional check, the loading status of each weapon (i.e., contents of chamber and magazine) was determined. Because the standard procedure for each officer was to always have a round in the chamber and a full magazine, the total number of shots fired by each officer could theoretically be determined by subtracting the number of rounds remaining in each weapon from the total magazine capacity plus one (the round in the chamber). This, of course, presumes that each officer did follow the procedure and begin with a fully loaded weapon. It further presumes no reloading during the shooting.

In the event that one or more fired cartridge cases were not found, the count would be thrown off, and there might not be any way to determine if fewer shots were actually fired or if less than maximum loading was responsible. Nonetheless, the loading status of all firearms involved was the appropriate thing to do. As it turned out, there was a discrepancy between the loading status of the weapons and the number of fired cartridge cases that could not be resolved. This added to the problems generated by the circumstances of the shooting in general and no doubt was a factor in an out-of-court settlement of a lawsuit filed by the family of the deceased.



Scene Documentation of Firearm

Date__________________ Location____

Case #_________________ Time collected_______ Collected by___________________

Type____________ Make______________ Model_____________ S/N_____________

Caliber/gauge________Finish____

Type/position of safeties____

Visible damage/alteration____

Trace Evidence (type/location)____

Other observations____

Loading status (brand/live or fired):

Chamber(s)____

Cylinder (capacity/contents – also complete diagram below)____________________

____

Magazine (capacity/contents) ____

Revolver cylinder: Draw in chambers & indicate cylinder rotation direction, chamber contents (headstamp/fired or unfired) and presence of halos on face

Figure 5.36 Loading diagram.

Exercises

1. A round nose lead bullet is found at a shooting scene. On closer inspection, the scene investigator notes that no rifling impressions are present on the bullet. Is there any way to visually determine whether this bullet may have actually been fired?

   Answer: This is likely a cast bullet of the type reloaders use. Many times there will be grooves near the bullet base that are filled with lubricant (frequently red or blue in color). If that lubricant is still intact, the bullet was not fired (otherwise the lubricant would be gone).
2. A revolver is recovered at the scene of an alleged suicide. The cylinder of the weapon is determined to rotate counterclockwise. There is a fired cartridge case under the hammer and a fired cartridge case in the chamber to the immediate right. What does this suggest?

   Answer: The counterclockwise rotation direction of the cylinder means that, if the two fired cartridge cases were fired sequentially, there should be a fired cartridge case to the left not right of the one under the hammer. This suggests that the weapon either was not fired sequentially or the cylinder was opened, rotated by one chamber, and then replaced.
3. What could be used to determine whether the two fired cartridge cases found in the revolver in exercise 2 were sequentially fired?

   Answer: Cylinder flares on the face of the cylinder, if present, could answer that question. The last cartridge fired should have produced a cylinder flare that overlaps each cylinder flare on either side.
4. Several shot pellets are recovered from a wall; the pellets are determined to have an average diameter of approximately 8.4 mm. What shot size is indicated?

   Answer: 00 Buck.
5. A shooting victim has three bullet entry wounds with no exits. Five bullet perforations are found in the exterior wall of the mobile home the victim's body was found in. No fired cartridge cases are found. How should the scene investigator begin her analysis of the shooting?

   Answer: The first thing she should do is shot accounting. An assessment needs to be made of the bullet entries in the body and the wall to determine if only one or more than one firearm appears to be involved (i.e., all the bullet entries appear to be similar in caliber). Assuming they all appear to be more or less similar in size (or no determination can be made), the fact that there are no fired cartridge cases present suggests that a revolver was used (it is possible the fired cartridge cases were picked up, but not likely). If there is a single gun involved and it is a revolver, the next thing to consider is whether there is an eight-shot revolver (because a total of eight shots appear to have been fired). There are eight-shot revolvers, but a firearm examiner will have to examine the rifling marks on the fired bullets to determine whether one gun or more than one gun was responsible.
6. What possible on-scene examination could be carried out to possibly determine whether one gun or more than one gun was involved?

   Answer: The scene investigator could simply hold any recovered bullets base to base to see if the rifling appears to line up. But because there are bullets still in the body, no valid answer as to the number of firearms used may be ascertained on-scene in this instance.

7. What do .38 special and .357 Magnum cartridges have in common?

   Answer: They both have bullets that are of the same caliber (cross-sectional diameter), that being 0.357 inch.
8. What is a subcaliber device?

   Answer: A device that allows a weapon to fire a smaller caliber bullet than it is designed to fire (i.e., .223 in a .30 caliber).
9. A bullet is found at a crime scene that has no rifling impressions, but there is other evidence that it was fired. What possible explanations could account for this?

   Answer:
   a. The bullet was fired in a slightly oversized barrel.
   b. The bullet was fired in a barrel with worn rifling.
   c. The bullet was fired in a barrel with no rifling.
   d. A sabot was used to fire the bullet.
10. A plastic shot cup is found at the scene of a shooting involving a shotgun. A measurement of the shot cup diameter shows it to be approximately 0.8 inch. What gauge shotgun was involved?

    Answer: The bore diameter of a 12-gauge shotgun is approximately 0.78 inch; thus, the shot cup is consistent with 12 gauge.
11. The slide of a semiautomatic handgun at a shooting scene is observed to be locked back. What does this indicate?

    Answer: Either the last round was fired or the slide was manually locked back (as indicated by rounds remaining in the magazine).

Suggested Readings

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Shooting Reconstruction Equipment and Its Use

6

A substantial amount of equipment must be available to the scene investigator in order to be able to properly evaluate a shooting scene. Commercially available "trajectory kits," such as pictured in Figure 6.1, provide only the basics in equipment needed. An experienced shooting scene investigator will doubtless add various equipment items, many of which may be of their own construction. The adaptation of equipment designed for other purposes (e.g., building construction, engineering, and architectural design) is also relatively common. To imagine that one might purchase a commercially available kit that is sufficient for all circumstances likely to be encountered at shooting scenes is soon determined to be folly in the course of the job. A number of the many items required for shooting reconstruction shown in Figure 6.1 are "add-ons" to the basic kit.

Documentation of Bullet Holes at Shooting Scenes

Proper documentation of bullet holes at shooting scenes should involve a series of steps as follows:

1. Examine the area around the bullet hole and the margins of the hole for trace evidence (i.e., blood, hair, fiber, tissue, glass, paint, gunpowder).

   If present, document photographically (see next section) and collect as appropriate (refer to Chapter 11 for instructions on how to collect gunpowder particles). It is best to collect the object itself, or a portion thereof, containing the bullet hole with trace evidence whenever possible and following proper documentation (photographs, measurements, and sketches). This permits examination/collection to be done back at the crime laboratory under more ideal conditions. Examination for and collection of blood are shown in Figures 6.2 and 6.3, respectively.
2. Document bullet holes/impact sites photographically before removing any trace evidence, adding markers, scales, and trajectory rods or otherwise altering the substrate (note: photographs will be repeated following addition of markers, scales, rods, etc.).
   - Photographs should be taken at three relative distances: distant, intermediate range, and close-up.
   - Photographs must be taken with the camera back parallel to the substrate plane (i.e., the camera lens held perpendicular to the substrate).
   - Photographs taken with trajectory rods in place must include a side view and an overhead view.
3. Measure the bullet hole (when appropriate) and record the dimensions.

   Bullet holes that are clearly highly distorted do not provide any useful information in terms of gross measurements (see Figure 6.4).

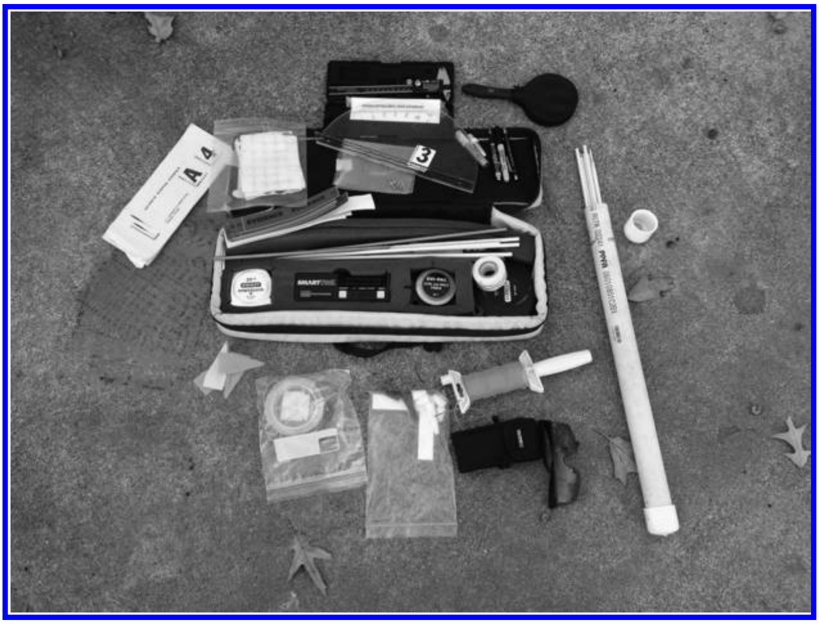

Figure 6.1 Trajectory kit.

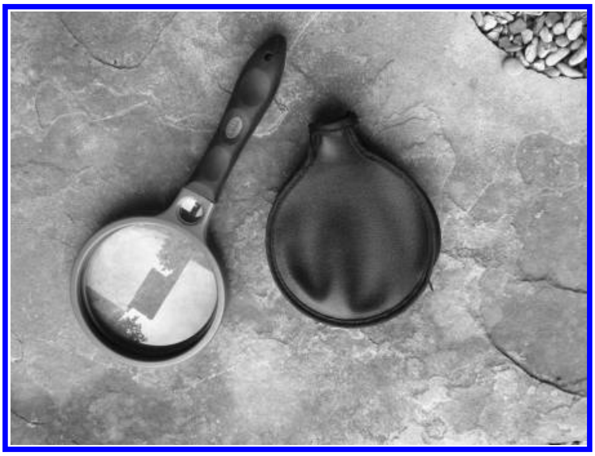

Figure 6.2 Hand lens.

Taking scaled photographs of highly distorted holes will suffice in the event that the hole dimensions might be desired for some reason at a later date, as illustrated in Figure 6.5.

If the hole appears circular, a quick check of hole width in two opposing directions should be made to verify this (e.g., if the hole dimensions are approximately equal in two opposing directions, the impact angle is approximately 90°). Bullet holes resulting from impacts at less than 90° will typically have an ovoid shape. A pair of calipers allows quick, accurate measurements to be taken. It must be remembered that in many instances the bullet hole will be slightly larger than the bullet diameter (caliber) because of bullet expansion upon impact. The bullet hole

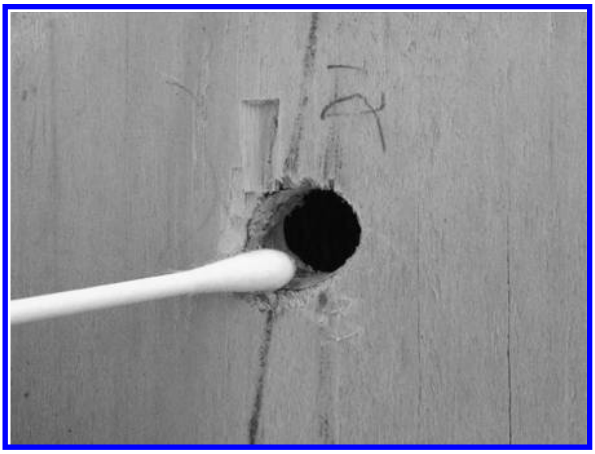

Figure 6.3 Removing apparent blood prior to trajectory rod insertion.

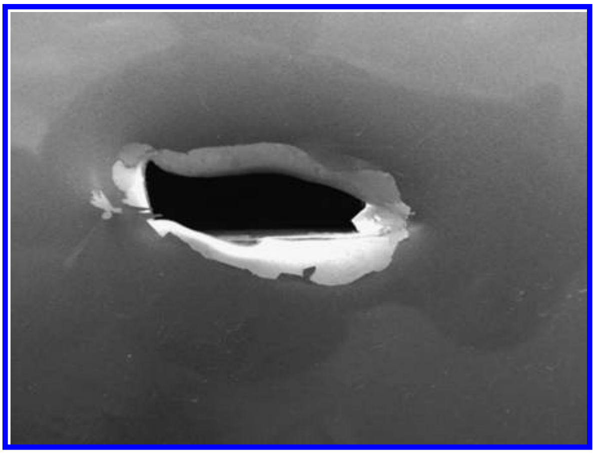

Figure 6.4 Distorted bullet hole in a car door.

may be significantly larger than the bullet diameter and irregular in shape owing to stretching/tearing of the substrate. This is frequently seen in vehicle body panels. In these instances, the "best fit oval" may be approximated using an engineering drawing template. This is illustrated in Figures 6.6 through 6.8.

These templates typically provide "idealized" ovals in 5° increments (e.g., 20°, 25°, 30°). Given that the generally accepted margin of error for determination of angles in bullet hole trajectory analysis is ±5°, this is a suitable tool. The template allows the investigator a means to approximate the "best oval" without resorting to guesswork.

Bullet holes that are more uniform in shape and have little or no apparent distortion should be measured with calipers for length and width. The key to avoiding, or at least minimizing, error is to place the inside diameter jaws (the small end of the calipers) as near to the top of the substrate as possible. Doing otherwise, especially when one jaw protrudes deeper than the other, creates unnecessary error. Practicing on holes of known incident (impact)

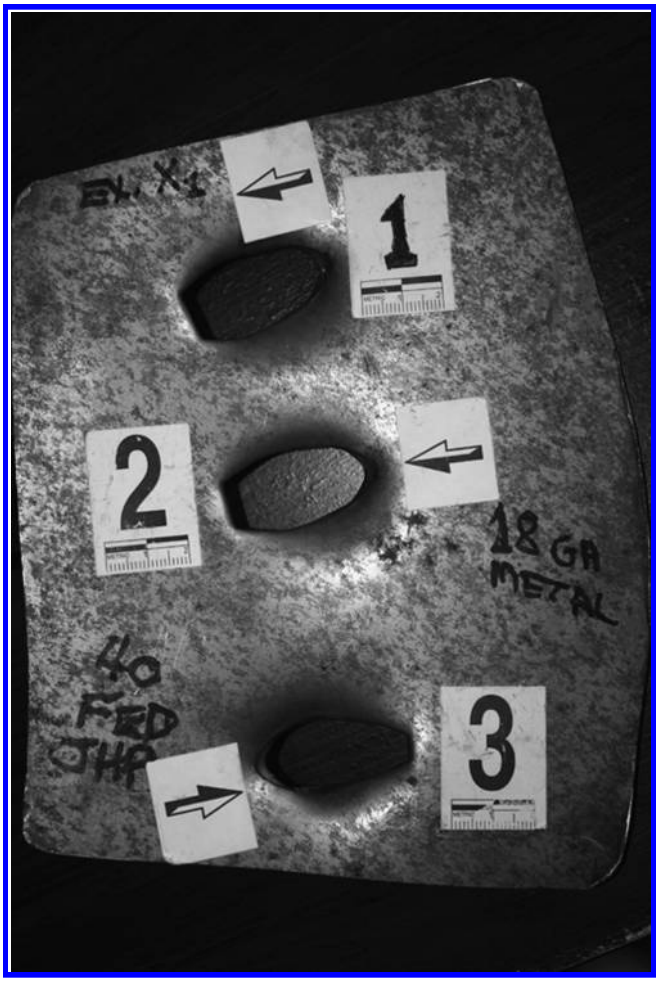

Figure 6.5 Scaled photos of distorted bullet holes.

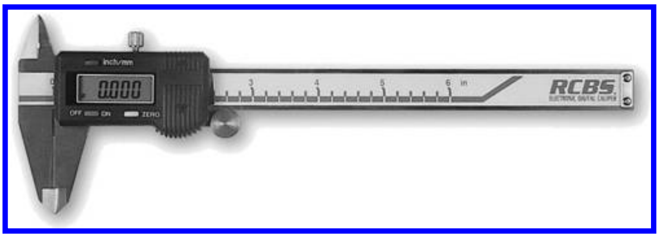

Figure 6.6 Digital calipers.

angles can help minimize error. Measuring hole dimensions is illustrated in Figures 6.9 and 6.10.

4. Fix the position of the bullet hole by establishing the *x*, *y* linear coordinates.

   This is standard crime scene procedure for documenting location based on fixed objects at the scene. For example, suppose the bullet hole is in an interior wall of a building. The height above the floor would provide the *y* coordinate, and the distance to the nearest intersecting wall could be used as the *x* coordinate.

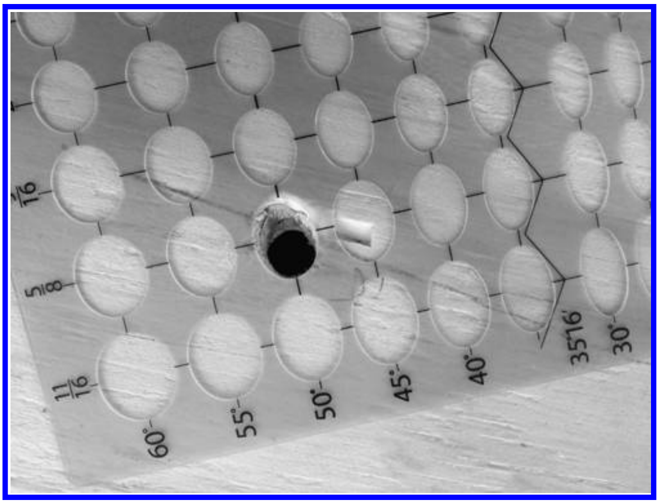

Figure 6.7 Template used to determine incident angle.

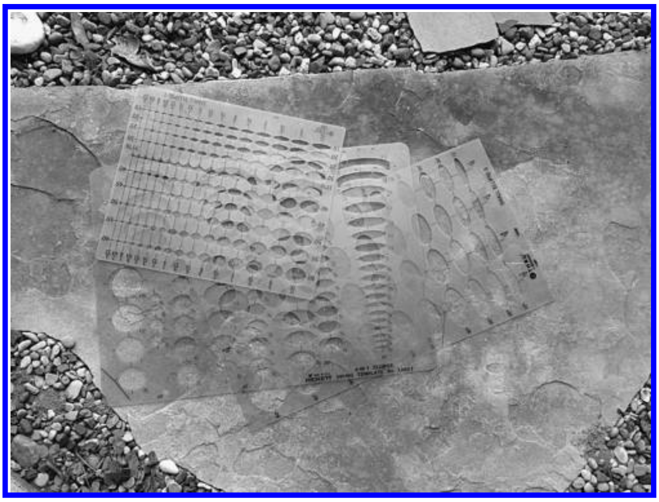

Figure 6.8 Templates for incident angle approximation.

For vehicles, it is useful to relate all bullet holes to a common point of reference. In this way, measurements of distances between holes can be easily calculated. The plane of the front of the vehicle (or the rear) provides a convenient point of reference in many instances. The ground is typically another point of reference. If a vehicle is sitting on an irregular surface (say, partially up on a curb) or has one or more flat tires, it becomes a bit more complicated, especially as it is unlikely that there will be any reliable information as to when the bullets struck in relation to when the vehicle went up on the curb and/or when the tires went flat. One way the author has used to take care of such situations has been to take the measurements as is, where is and then level the vehicle (using floor jacks and jack stands) and remeasure. The linear coordinates typically used are illustrated in Figures 6.11 and 6.12.

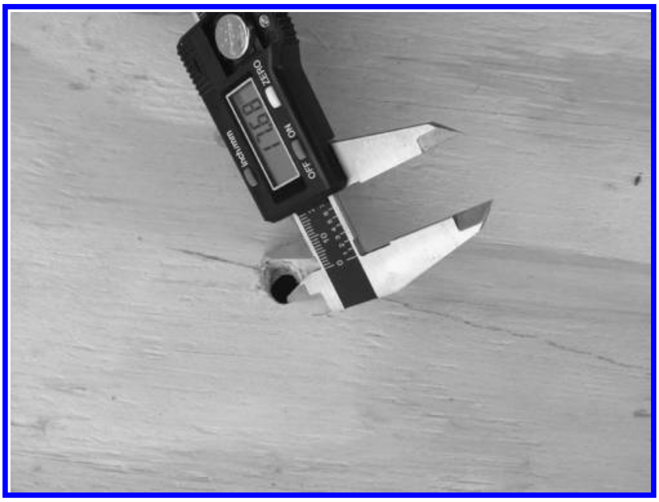

Figure 6.9 Measuring hole length.

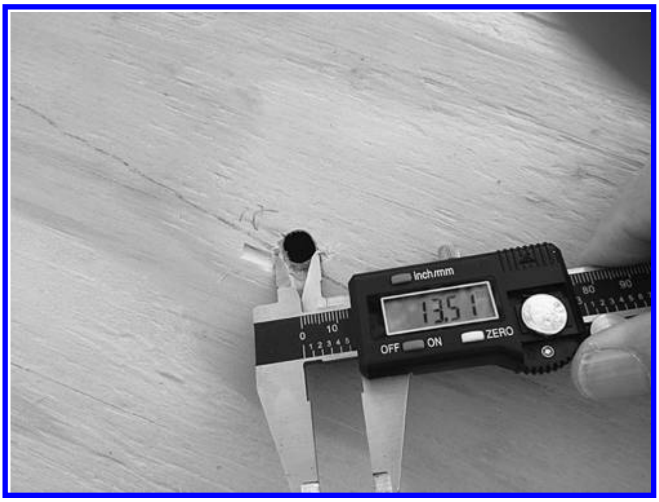

Figure 6.10 Measuring hole width.

5. Determine the *x*, *y* angular coordinates of the bullet hole.

   There are two angular components for each bullet trajectory associated with a bullet hole that we can designate as *x* and *y*. This designation applies to any substrate orientation. There are three different possibilities as to which angle we designate as *x* or *y* (depending on the perspective) as shown in Diagram 6.1. By convention, we shall typically select the acute angle (less than 90°).

   These angular components or coordinates are illustrated in Figures 6.13 and 6.14.

   These angular components are determined by inserting trajectory rods into the bullet holes and measuring the angles (as is explained in the section "Trajectory Rods and Their Use at Shooting Scenes"), by calculation from the hole dimensions and the hole axis or by using a template.

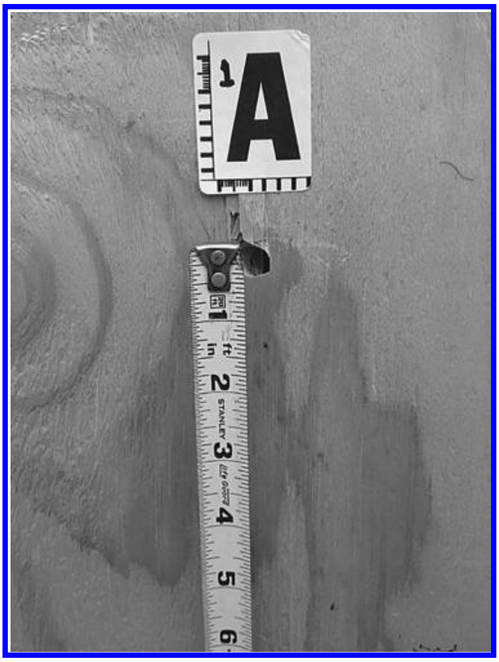

Figure 6.11 Y linear coordinate.

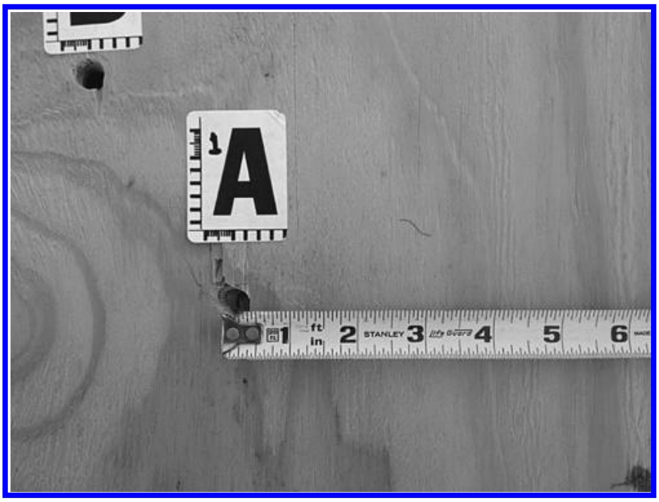

Figure 6.12 X linear coordinate.

INCIDENT (IMPACT) ANGLE CALCULATION

Using the values indicated in Figures 6.9 and 6.10, we can calculate the incident (impact) angle for the bullet hole shown. This is done by dividing the hole width by the hole length and then finding the arc sine of the quotient. This requires a scientific calculator (found on most smart phones or available as an app). Thus, the following are required steps:

hole width = 13.51 mm   hole length = 17.68 mm

$$w/l = 13.51/17.68 = 0.7641$$

The arc sine of 0.7641 = 49.83° or about 50°

This is the acute (less than 90°) angle between the bullet trajectory and the substrate. Compare the calculated value with that obtained using the template (see Figure 6.8). You will note that with both methods the approximate angle of 50° was obtained.

To quote one of my students in a previous in-service class, "This stuff actually works!"

The assignment of x, y axes for a substrate in which there is a bullet hole is purely arbitrary. What is important is that the investigator take notes and make sketches to designate what is being referenced as the x axis and what is being referenced

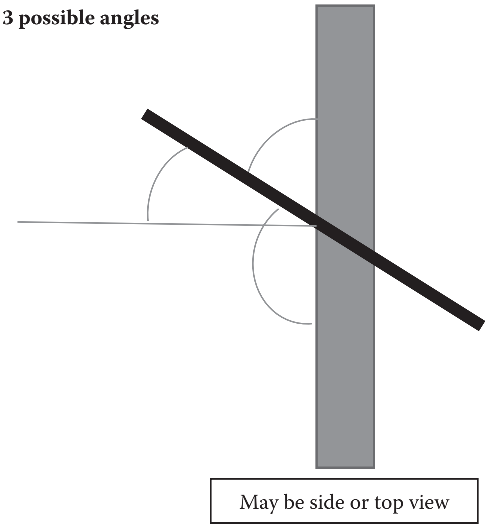

Diagram 6.1 Possible angle designations for any trajectory.

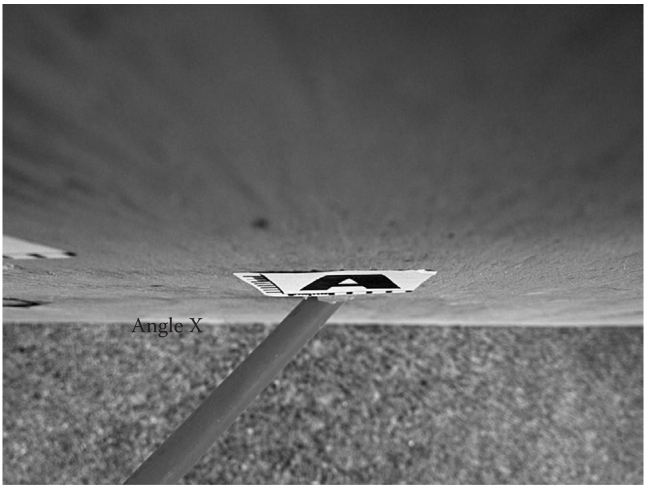

Figure 6.13 Angle X (acute angle from rod to left face of substrate).

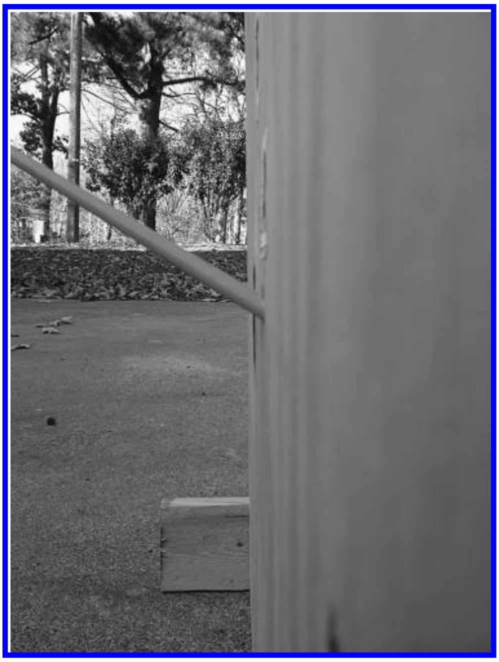

Figure 6.14 Angle Y (acute angle from rod to top of substrate).

as the *y* axis. For example, suppose the bullet hole being documented is in a vertical wall. The logical approach would be to establish the vertical direction as *y* and the horizontal direction as *x* (standard graphical orientation). In this example, the smaller of the two vertical *y* angles would be defined as the angle of impact, whereas the smaller of the two horizontal *x* angles would be defined as the lateral angle (or azimuth). However, the *x* and *y* designations could just as easily be assigned in the opposite order without any problem just as long as this was appropriately recorded in the investigator's notes. Suppose that the surface the bullet hole is in happens to be horizontal rather than vertical or neither horizontal nor vertical but obliquely oriented—what then? Again, it is simply going to be up to the discretion of the investigator as to how to designate the orientation of the axes. In general, the impact angle is the minimum or smaller angle between the axis of the impinging bullet and the surface, and the lateral angle is the minimum angle between the axis of the impinging bullet trajectory and either side. Figures 6.15 and 6.16 provide some examples.

Figure 6.17 illustrates the use of an angle gauge in measuring angles of inclination/declination associated with vertical substrates. One must recognize that the angle being measured is relative to a perpendicular point to the substrate (the middle angle shown in Diagram 6.2).

The measurement and documentation of the two angles associated with each bullet trajectory is an essential part of the documentation of bullet holes at shooting scenes. By properly measuring and recording these angles, the investigator will be able to prepare scale drawings to assist in the analysis of the shooting incident and to present them to the jury as demonstrative evidence. This results in two perspectives that should be evaluated for purposes of establishing whether a

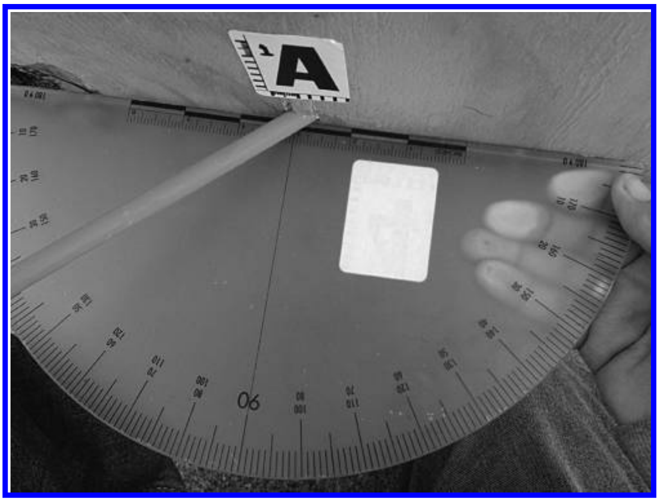

Figure 6.15 **(See color insert.)** Measuring angle X with a protractor.

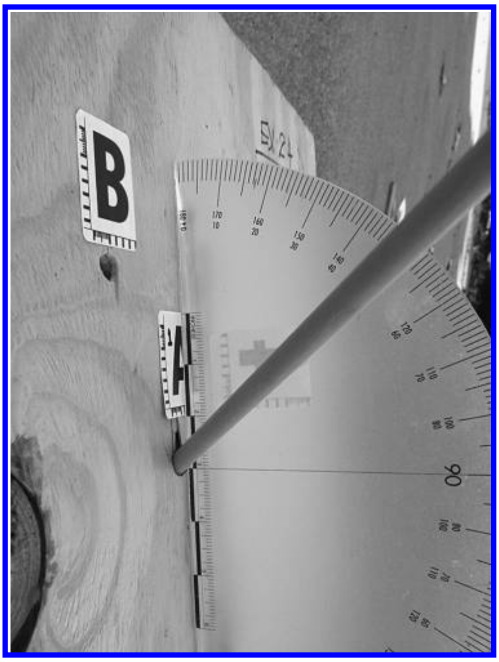

Figure 6.16 **(See color insert.)** Measuring angle Y with a protractor.

particular shooter position is possible or impossible, as illustrated in Figures 6.18 and 6.19.

Although two-dimensional (2-D) diagrams can still be very effective in illustrating trajectories, 3-D diagrams offer obvious advantages such as “infinite” perspectives as seen in Figure 6.20.

6. Special considerations in documenting bullet holes.

There are a number of special considerations when bullet holes are found in elastic media, such as plastic vehicle components and tires, and in all types of glass. These situations are discussed in more detail in Chapter 12. As far as elastic media

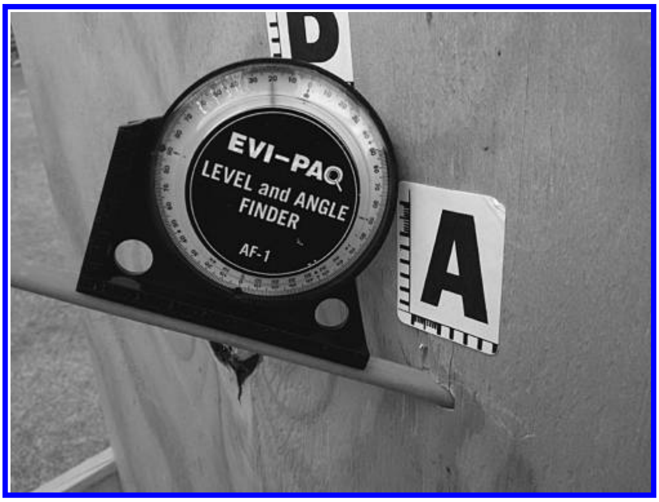
EVI–PAQ
LEVEL and ANGLE FINDER
AF-1
B
A

Figure 6.17 Using an angle gauge (this actually measures the angle of elevation or declination from a perpendicular to the substrate).

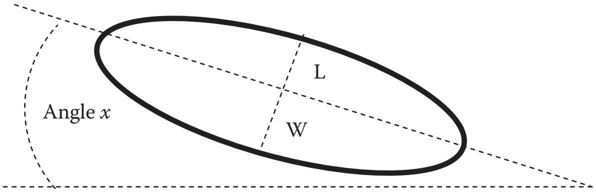

Diagram 6.2 *x*, *y* angle calculation. L = length and W = width.

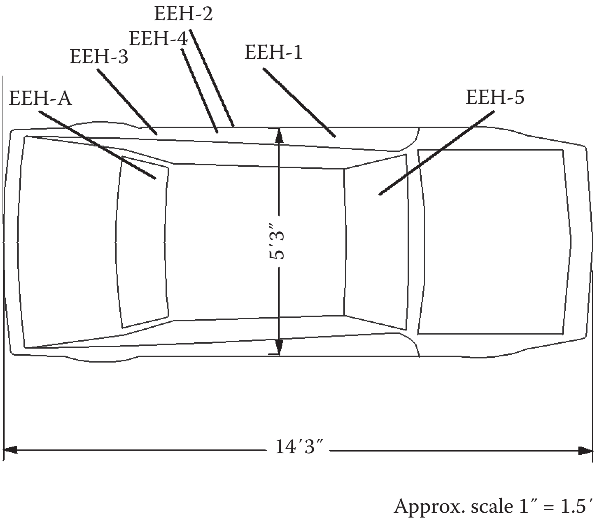
EEH-2
EEH-4
EEH-3
EEH-1
EEH-A
EEH-5
5′3″
14′3″
Approx. scale 1″ = 1.5′

Figure 6.18 Top view.

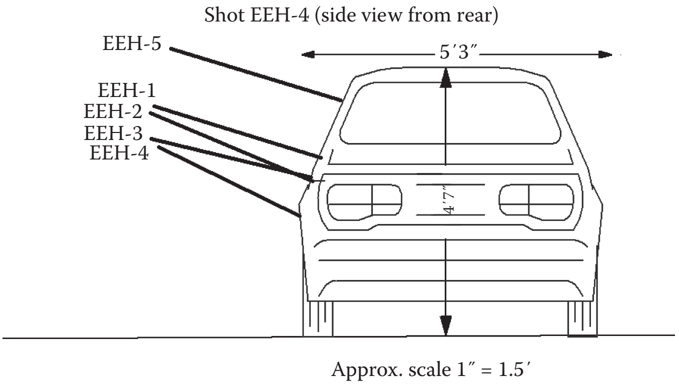

Figure 6.19 Side view.

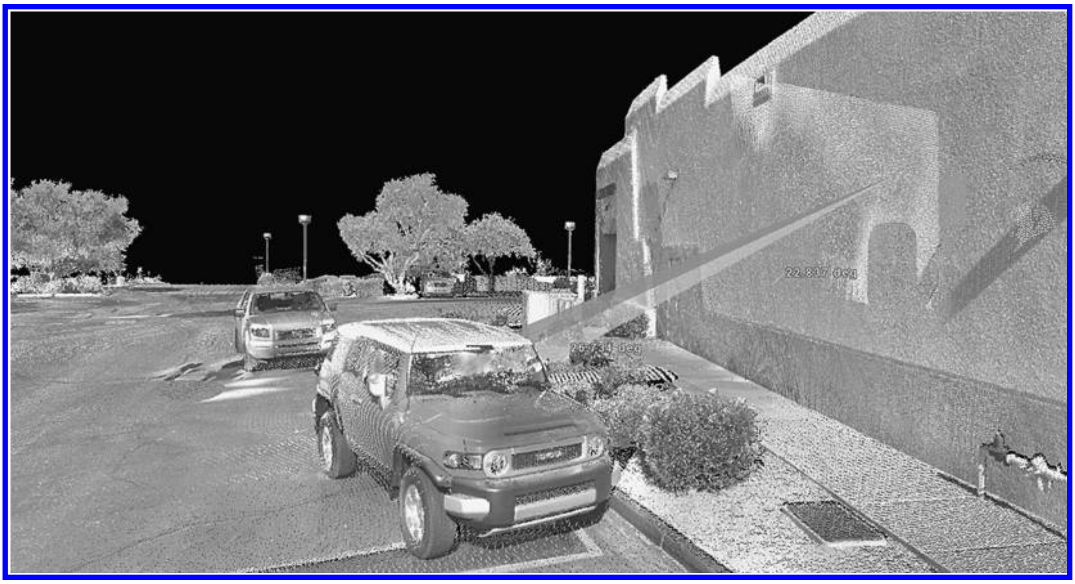

Figure 6.20 **(See color insert.)** 3-D laser scan by Michael G. Haag.

are concerned, there will typically be the equivalent of an abrasion ring around the margins of the hole. The hole will be smaller than the bullet diameter because of the elasticity of the media (analogous to bullet holes in skin). With plastic vehicle components, there will often be a concave area around the hole. By measuring the diameter of the outer perimeter of the visible defect (abrasion or concave area), a reasonably close approximation of caliber may be obtained. However, the best policy is to merely record the measurement without referring to it as "caliber" owing to the variables in elasticity of various substrates and the potential for misleading appearances. This is illustrated in Figures 6.21 and 6.22.

With regard to bullet holes in glass, it is important to document the presence of beveling around the hole margin. *The beveling is found on the exit side* (see Figure 6.23). It is also important to note and document the fracture pattern around the hole (see Chapter 12 for an explanation of bullet holes in glass). Special considerations for the documentation and analysis of shots fired into vehicles are discussed in Chapter 13.

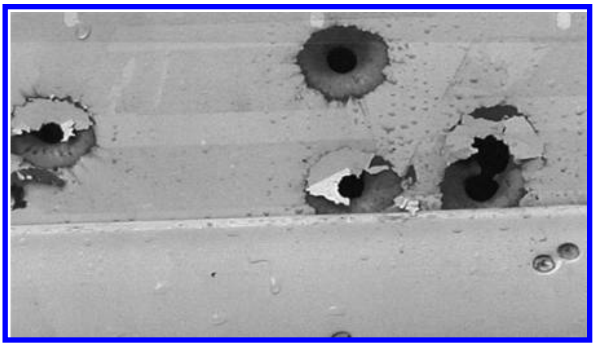

Figure 6.21 Bullet holes in police vehicle door and molding (all same caliber).

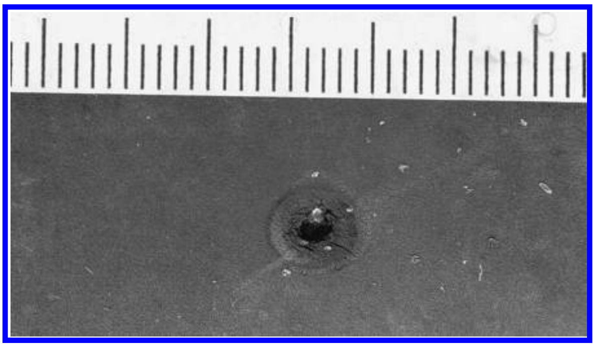

Figure 6.22 Bullet hole in tire sidewall from 9 mm hollow point.

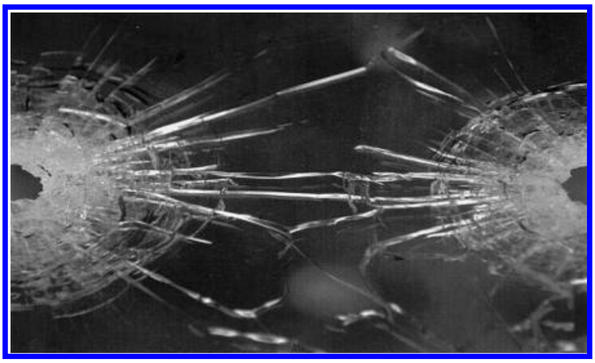

Figure 6.23 Bullet holes in windshield glass (exit side).

Trajectory Rods and Their Use at Shooting Scenes

Trajectory rods are useful for the determination of bullet trajectories in the reconstruction of shooting incidents. A variety of different rods are useful for investigators because of the varying conditions and materials found at crime scenes. It is important to know and understand the special techniques associated with trajectory rod usage. Trajectory rods are placed through bullet holes (see Figure 6.24) to help the shooting scene investigator establish the approximate shooter position and also to assist in determining the point of impact of bullets passing through various objects.

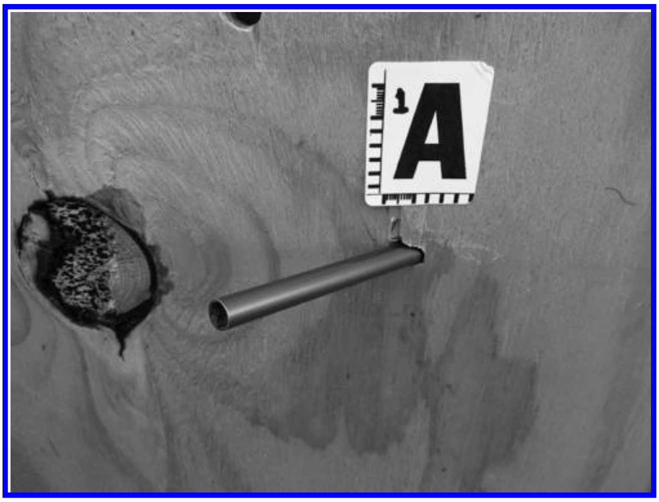

Figure 6.24 Trajectory rod in place.

The impact angles (both the interior and the lateral angle) can be calculated using trajectory rods. This is particularly applicable when bullets pass through doors or walls. By marking the trajectory rod at the entry surface and also at the exit surface, the distance the bullet traveled through the object may be measured. This distance then forms the hypotenuse of an imaginary right triangle used to calculate the associated angle desired. This is illustrated in Diagram 6.3.

An assortment of types and sizes of trajectory rods are useful to have at the scene in order to be able to work with a wide variety of media. The addition of various accessories

1. Mark 2 trajectory rod/substrate intersections
2. Remove rod and measure span between marks
3. Draw right triangle with hypotenuse equal to span
4. Calculate 2 acute angles (entry and exit angles)
5. Calculate thickness of substrate (base of triangle shown)

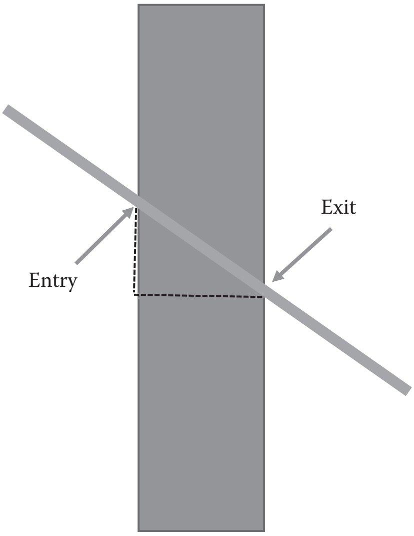

Diagram 6.3 Calculating angles and substrate thickness.

to trajectory rods, such as specialized tips and lasers, greatly expands their utility. A trajectory rod assortment may be had by purchasing wooden dowels of varying diameters and painting them with fluorescent paint. Diameters should be selected to approximate commonly encountered calibers (e.g., 9 mm/.357, .40, .45). The rods should be color coded to the particular caliber. A useful addition is the insertion of screw eyes into the wooden rod ends to allow string attachment (which can be color coded as well). This way, multiple calibers can be visualized in shootings by color. Figures 6.25 through 6.27 illustrate these concepts.

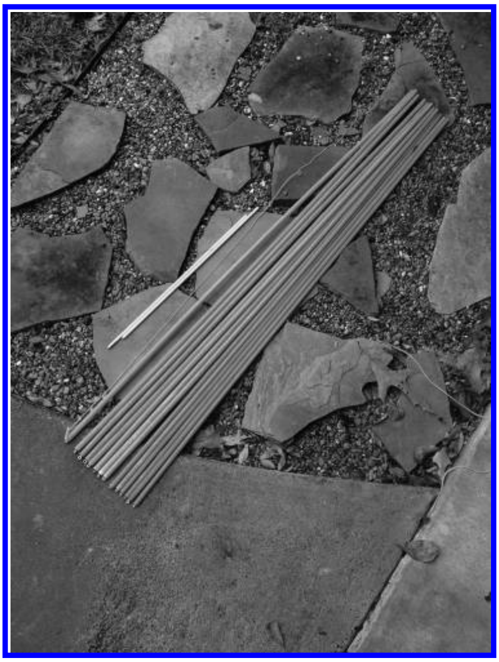

Figure 6.25 **(See color insert.)** Color-coded trajectory rods (top 2 rods: 9 mm; middle 8 rods: 40 cal; bottom 6 rods: 45 cal).

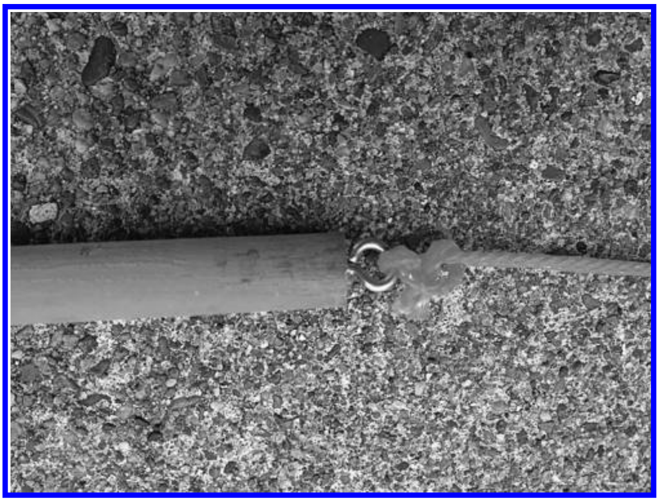

Figure 6.26 Eye for string attachment.

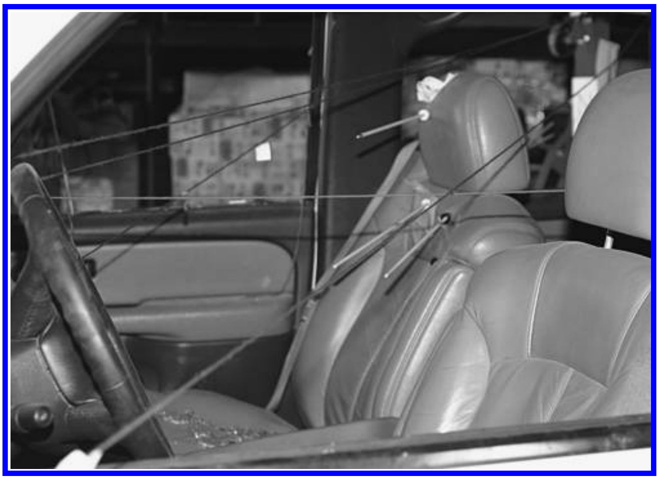

Figure 6.27 **(See color insert.)** Color coding two different calibers.

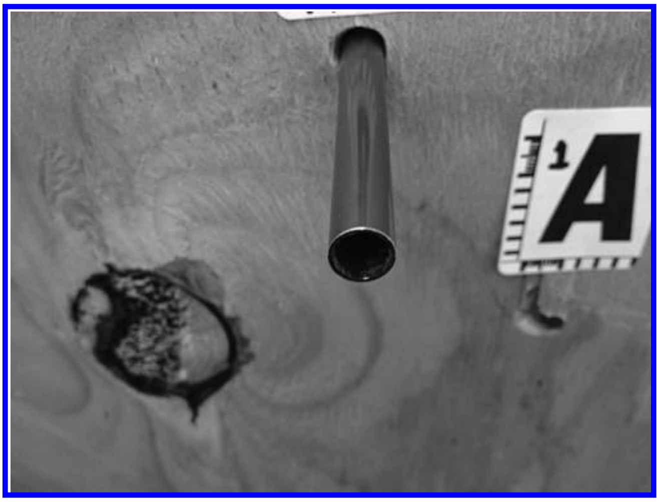

Figure 6.28 Use of a tube for trajectory analysis.

Another useful “trick” is to use a tube rather than a rod for insertion into bullet holes involving distant shots. By simply looking through the inserted tube, the investigator may be able to locate a likely area of origin for a distant shot, as illustrated in Figure 6.28.

The author was called to the scene of a sniper shooting that involved a shot that perforated the driver door of a van and killed the driver. The shot came from several hundred yards away where there was a tree line in an otherwise open terrain. The tree line was too far away to allow use of a laser to help define the likely shooter position. The author happened to have a piece of aluminum tubing of the appropriate length and diameter in his crime scene vehicle. The tubing was inserted through the bullet entry and exit. By looking through the tube and then looking across to the tree line, it was possible to visualize an area that appeared to be the likely origin of the shot.

Upon walking out to the area seen through the tube, a fired 30-06 rifle cartridge case was found on the ground along with disturbances in the soil suggestive of a prone shooter. The markings on the fired cartridge case were later confirmed as having been made by a rifle recovered from a suspect whose pickup was stuck in the mud a short distance away in the forest.

An understanding of the correct placement of trajectory rods is essential to arriving at meaningful results. Proper documentation of trajectory rod placement involves taking two all-important photographs: (1) a side view and (2) an overhead or "bird's eye" view, as illustrated in Figures 6.29 and 6.30.

It is important for the investigator to realize, however, that the use of trajectory rods to help establish shooter position is not an exact science. Thus, the results obtained must be viewed as an approximation. Locating additional substantiating evidence, such as fired cartridge cases and trace evidence, can give added weight to the trajectory rod determination result. The use of trajectory rods to approximate shooter position is a well-established technique. However, it is essential that the investigator have a clear understanding of both the capabilities and the limitations of bullet trajectory rods and also know something about the associated use of lasers and mathematical calculations. It is generally accepted (and borne out in numerous field testing exercises conducted by the author) that the margin of error for trajectory angle determinations is ±5°. Thus, an angle of impact determined to be 20° should be understood to be within the range of 15–25° for example.

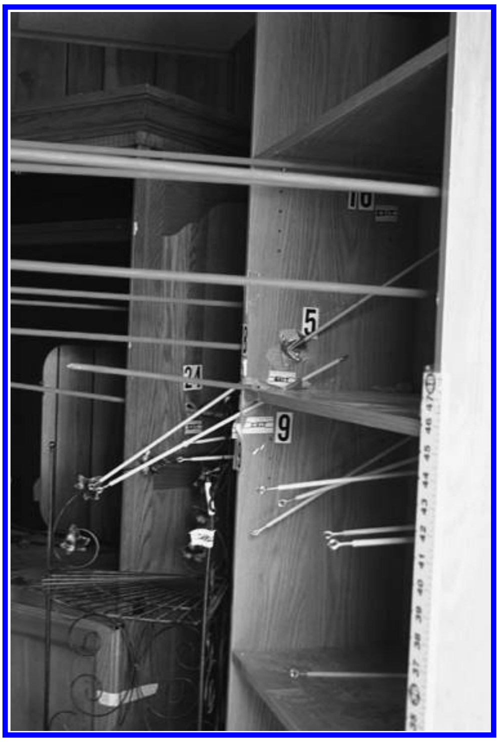

Figure 6.29 Side view of trajectory rods in place.

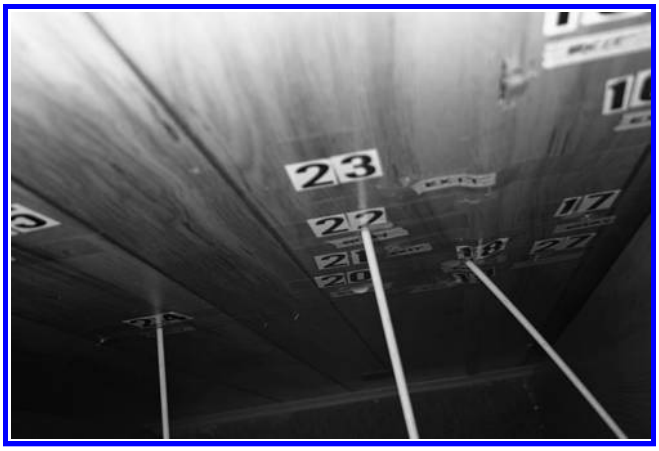

Figure 6.30 Overhead view of trajectory rods in place.

Bullet Hole Basics

Before attempting to use trajectory rods at a crime scene, some bullet hole basics need to be understood.

- Bullets striking at or near 90° produce virtually round holes.
- Bullets striking at less than 90° tend to produce oval holes.
- The lower the angle of impact, the longer the bullet hole.
- Angle of impact is mathematically related to the width and length of a bullet hole by the formula:

Sin of angle of impact = width/length

- Bullets tend to expand upon impact such that the hole diameter (width) produced will typically be slightly larger than the bullet cross-sectional diameter (caliber).
- The more unyielding a target is, the greater the difference between hole diameter and actual bullet cross-sectional diameter (unexpanded).
- In materials such as wood and sheet metal, the entry side of an oval bullet hole will typically have a visible shoulder, whereas the exit side will not.
- Bullet holes in double-walled objects such as car doors will often have large, irregular exit holes due to bullet expansion and the exiting of fragments from internal supports/mechanisms.

Figures 6.31 through 6.35 illustrate various bullet impacts into a car door.

Types of Trajectory Rods

As already discussed and illustrated, a wide variety of items may be used as trajectory rods in addition to commercially available trajectory rods. Sources for these include the following:

- Wooden dowels of diameters ranging from approximately 0.22 inch to approximately 0.50 inch are available from hardware/lumber outlets.

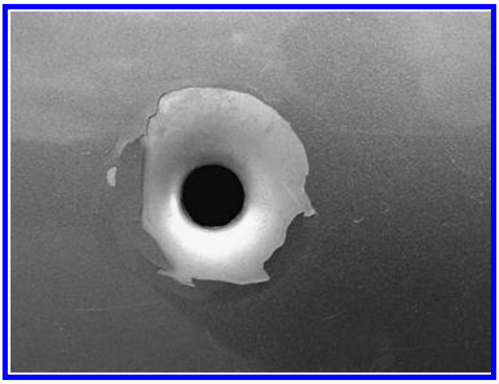

Figure 6.31 90° impact.

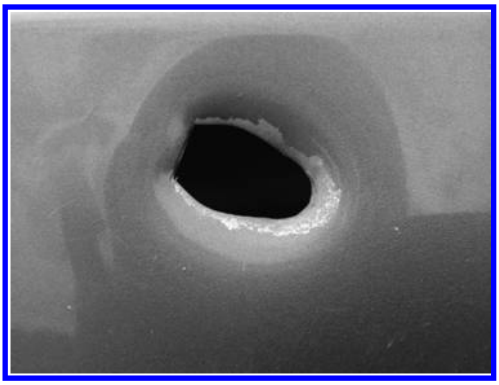

Figure 6.32 60° impact.

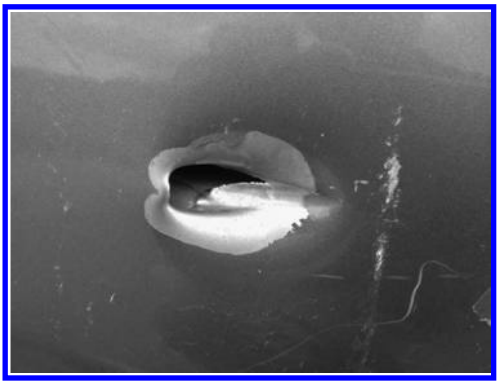

Figure 6.33 30° impact.

- Plastic-coated steel rods with screw-in connector studs that are produced commercially for this purpose by several crime scene suppliers (go online for specific suppliers).
- Colored fiberglass rods (available through crime scene supply companies).
- Tent poles (fiberglass with metal connectors—outdoor stores carry these).

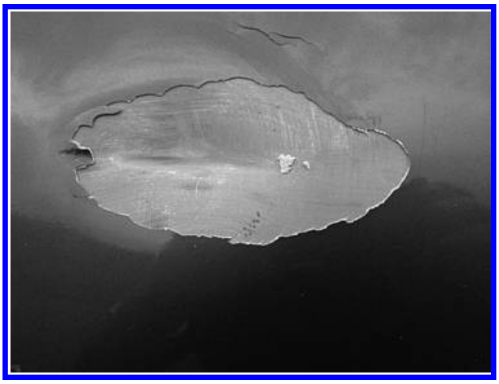

Figure 6.34 10° impact.

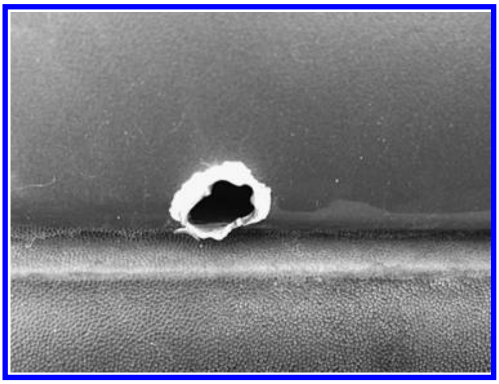

Figure 6.35 Exit hole.

- Aluminum tubes (arrow shafts work well as do gun cleaning rods).
- Steel tubes (automobile brake line comes in different diameters and can be cut to any length—available at auto parts stores).
- Brass tubes (available from hobby supply stores).

A handy holder for the trajectory rods can be easily made from a piece of PVC pipe by gluing a cap to one end and using another cap for a slip-on fit at the other end.

Trajectory Rod Accessories

A number of useful accessories are available and include:

- Centering cones (allow smaller diameter rods to work in larger diameter holes)
- Connectors (allow rods to be joined together)
- Tips for attaching strings (gun cleaning patch holders work well)
- Pointed tips (assist in passing rods through objects such as car seat backs)

These are illustrated in Figure 6.36.

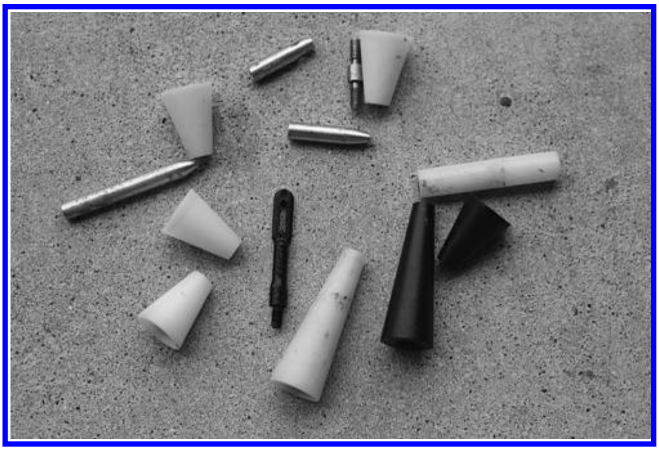

Figure 6.36 Trajectory rod accessories.

Other Equipment Required

A number of other items are necessary for use with trajectory rods in establishing probable bullet paths. These include the following equipment:

- Laser measuring device (for distance and angle measurement)
- Laser with trajectory rod attachment capability
- Handheld scientific calculator (with sin, cos, and tan functions)
- Plumb bob and string (used as a point of reference for trajectory rod angle determination with irregular substrates)
- Piece of black foam board approximately 8½ by 11 inches (laser target)
- Elastic string (eliminates the inherent tendency to sag and comes in various colors as well as black and white)
- Colored string (stringing kits are available through forensic suppliers)
- Reflective string (use with flash on camera)
- Evidence markers (letters, numbers both with and without adhesive backs)
- Measuring scales (adhesive back, magnetic, etc.)

A zero base protractor (Figure 6.37) differs from typical protractors in that the base of the protractor is the point of origin for angle measurement (i.e., the base is 0°). Standard protractors have the base line slightly above the actual protractor base. Using other than zero base protractors results in added error. The zero base protractors specifically designed for trajectory analysis are larger and easier to read than standard protractors. They also have an "L-shaped" profile that makes them easier to use on flat surfaces. At the same time, this makes them unsuitable for use on irregular surfaces. This is remedied by switching to an angle gauge or using a plumb line held out away from the surface as discussed in a later section ("Uneven, Curved Surfaces"). A useful companion to the full (180°) zero base protractor is the half-size (90°) version. This is useful when measuring in close quarters where obstacles prevent the use of the full-size protractor.

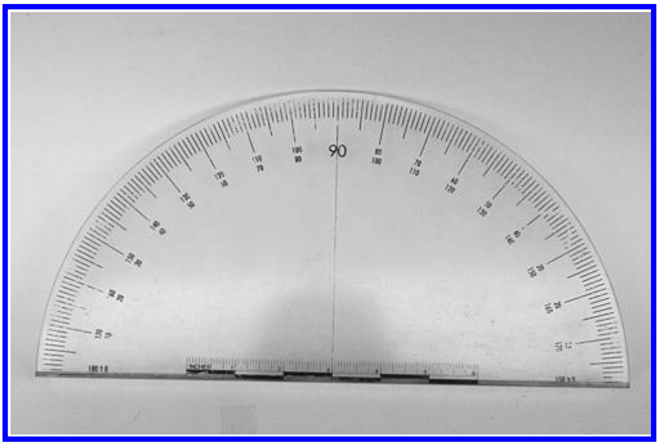

Figure 6.37 Zero base protractor.

Substrate Considerations

Different substrates present various considerations when using trajectory rods:

- Plywood and other laminates produce splintering and irregular exit edges (templates can solve many of these issues).
- Sheet metal can produce oversized, irregular entry holes (templates can solve many of these issues).
- Tempered glass typically produces irregular holes (no really good solution).
- Upholstered furniture and car seats can obscure bullet holes (use careful dissection of these items to locate bullet tract).
- Rubber tires can produce tiny holes with certain ammunition such as the .22 round nose lead (always dismount flat tires from rims and inspect inside surfaces).
- Structural walls and car doors often contain inner obstacles that alter bullet paths (interiors of these items must be inspected to confirm the absence of internal ricochet).

Proper Trajectory Rod Placement

Different conditions require different techniques.

- If a shoulder is present on the entry side of a bullet hole and centering cones are not used, the trajectory rod should be pressed against the shoulder to obtain the most accurate trajectory estimate. Centering cones should not be used at low angles (below 60°) owing to the introduction of added error (see Figures 6.38 and 6.39).
- If holes are large and/or irregular, centering the rods will give the best trajectory estimate (this may be accomplished by using centering cones, physically holding them, or using two strips of tape across the hole in an "X" pattern to create a support for the rod at the center of the hole).

Uneven, Curved Surfaces

Car body panels are often of irregular contours, making the measurement of trajectory rod angles difficult when using a trajectory protractor. To solve this problem, a plumb

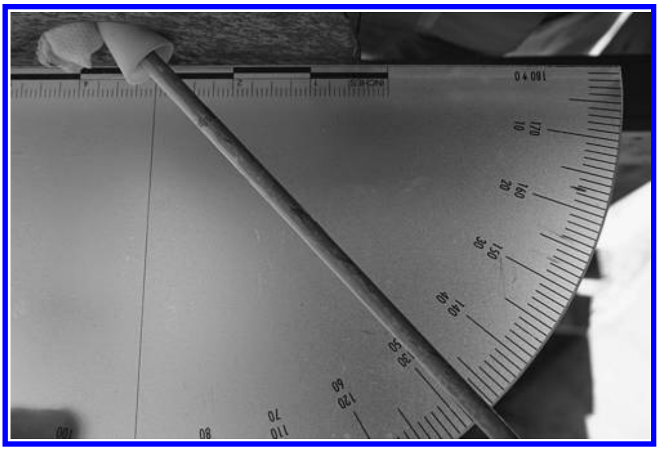

Figure 6.38 48° impact angle (IA) with cone.

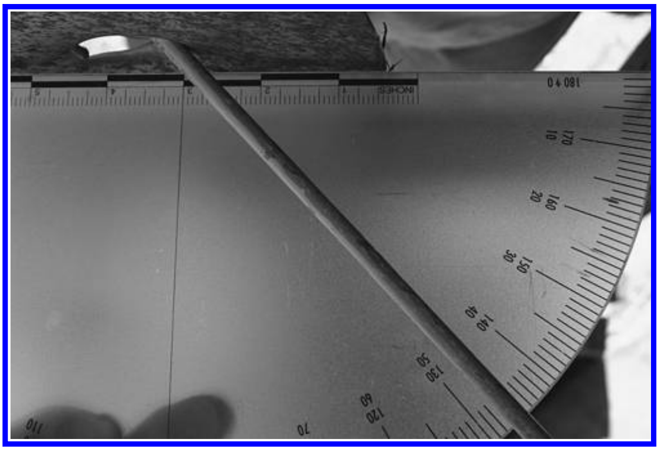

Figure 6.39 46° IA without cone.

bob is attached to a string and suspended alongside the body panel and next to the rod. The protractor is then lined up with the base along the plumb bob string and the angle of the trajectory rod in the vertical plane measured. In this way, multiple bullet holes in body panels are all measured with respect to the same reference (the plumb line) in the vertical plane. As an alternative, an angle gauge may be used for vertical angle measurements. An electronic, digital angle gauge can also be used. These are available at hardware and building supply stores. One such device, the Smart Tool™, is shown in Figure 6.40. These have the advantage of being more easily read and, hence, show up better in photographs.

Electronic measuring tools, such as the Leica Disto™, may also provide angle measurement capabilities. Typically, the device would need to be tripod mounted to do so.

Neither the mechanical angle gauge nor the electronic version works in the horizontal plane. Therefore, the use of the zero base protractor is the only solution. Horizontal angles require a particularly steady hand on the protractor if the surface is uneven in this plane, because the plumb line also only works vertically as well.

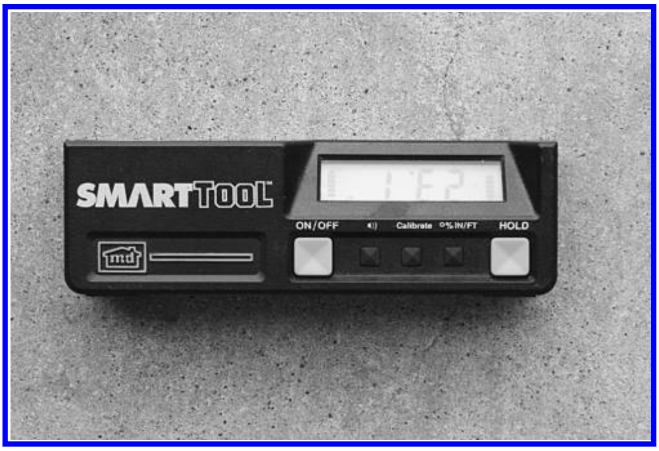

Figure 6.40 Smart Tool angle measuring device.

Rod "Extension" via Laser

A laser can "extend" the trajectory rod out to 100 yards or more if needed.

- Attaching a laser to the end of the trajectory rod allows for quick evaluation of maximum shooter position.
- Using a black target, such as a piece of foam board, the laser dot may be followed up range in conditions of bright sunlight (otherwise, it may be extremely difficult to see). Wearing red goggles extends the visible range of a red laser dot.
- Laser beams may be photographed in moderate to low lighting by setting the camera up on a tripod, setting the aperture on "Bulb" (maximum opening), and using a remote shutter release. Two individuals are generally needed, one to open/close the camera shutter and the other to "walk down" the beam using a handheld target (see Figure 6.41).

Use of Lasers, Strings, and Adhesive Dots

Sometimes it is more convenient to use strings to represent trajectories in close-range shots. When multiple calibers are involved, color coding everything is helpful for getting "the big picture," particularly when giving court presentations. It is, of course, possible to do all this digitally and/or use animation, but a simplistic approach can still be effective.

Step 1. Insert a trajectory rod with a laser (Figure 6.42).
Step 2. Determine the point of laser termination (maximum shooter position) (Figure 6.43).
Step 3. Place a color-coded marker at the point of laser termination (Figure 6.44).
Step 4. Connect a color-coded string between the termination point and the trajectory rod (Figure 6.45).
Step 5. Photograph the string from multiple positions.

Strings and related stickers are illustrated in Figures 6.46 and 6.47.

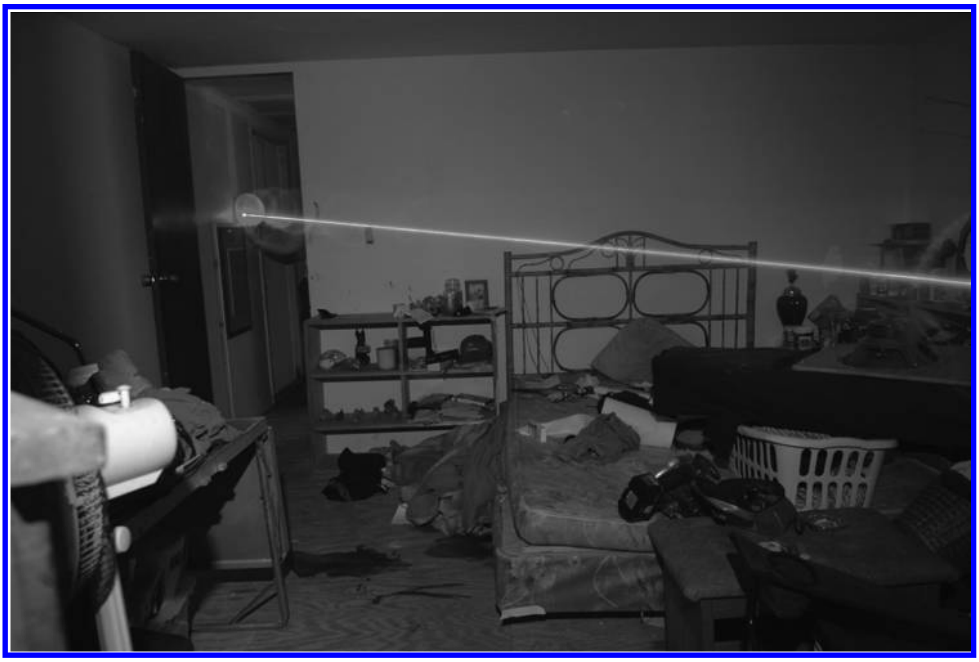

Figure 6.41 **(See color insert.)** Scene photo of laser.

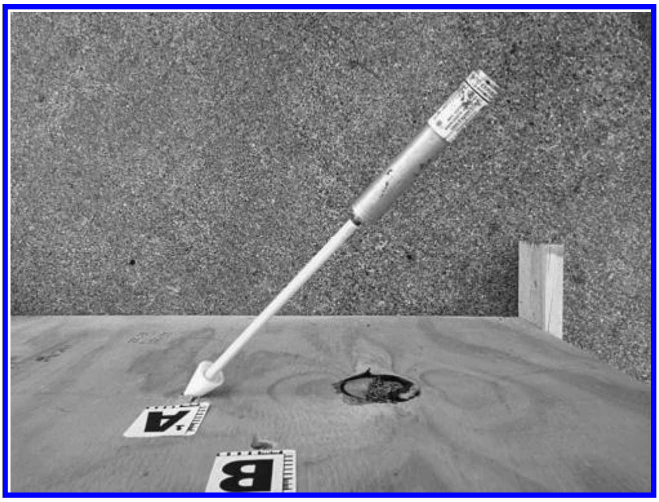

Figure 6.42 Laser-fitted trajectory rod.

Key Points to Remember

- Trajectory rod placement requires an understanding of the dynamics of bullet hole production.
- True bullet trajectories are parabolic, whereas lasers travel in straight lines.
- The trajectory that is established will be an approximation only.
- Because most shootings take place at close range, lasers provide reasonable trajectory approximations in those instances.
- At distances of about 10 yards and beyond, ballistics software provides more realistic trajectory representation than laser beams.

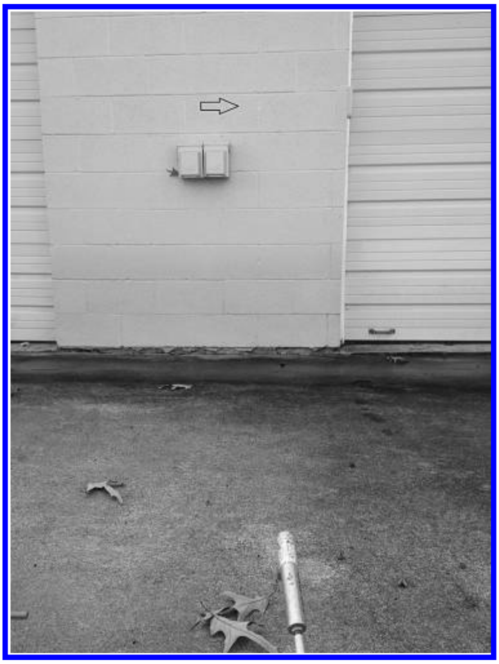

Figure 6.43 Laser termination (arrow).

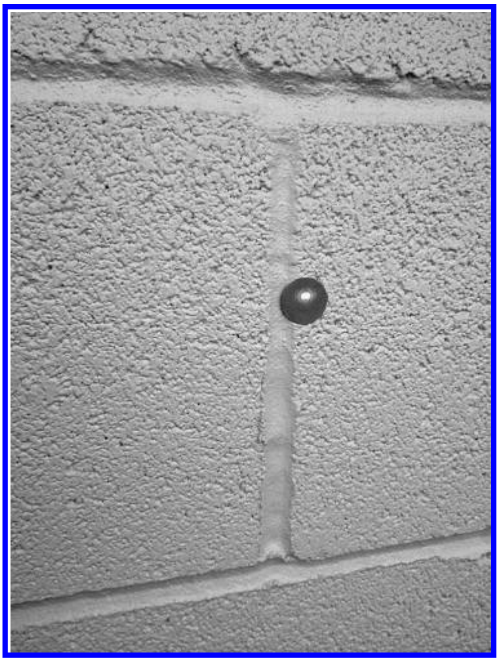

Figure 6.44 Laser termination marked with color-coded sticker.

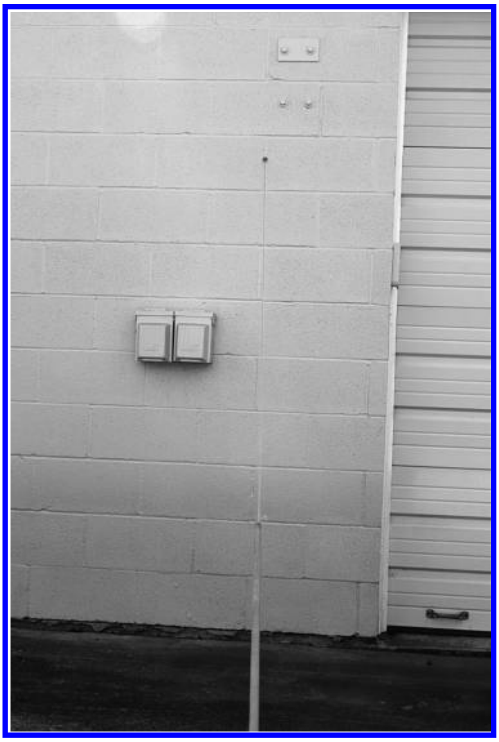

Figure 6.45 String from color-coded rod to laser termination sticker.

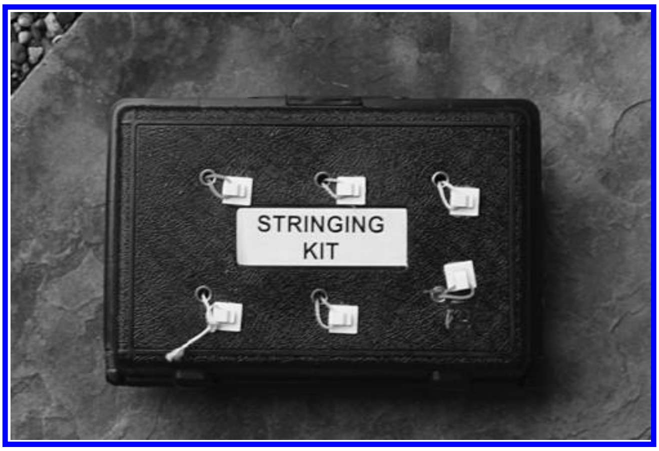

Figure 6.46 Colored string kit.

Sources of error in trajectory angle determinations:

- Bullet deviation upon impact—when bullets strike a substrate, there will frequently be some deviation, particularly when striking hard substrates at angles other than 90°.
- Improper positioning of trajectory rods—even under the best of effort, irregularities in the margins of bullet holes make positioning of rods difficult.

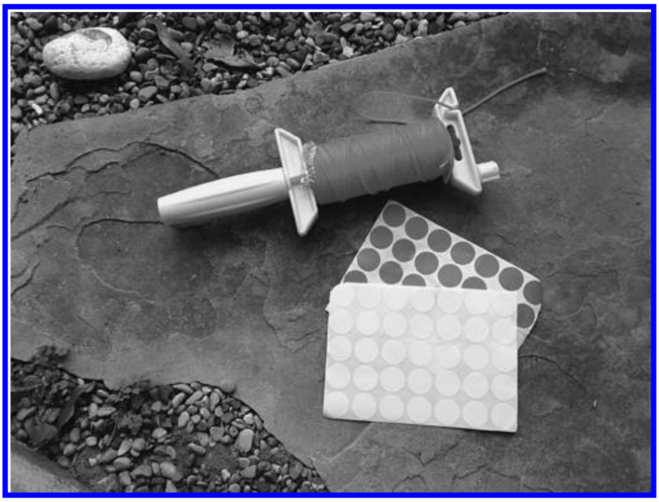

Figure 6.47 Colored string and stickers.

- Human error—not reading the measuring devices properly accounts for some of the errors.
- Internal deflection—failure to examine the inner areas of double-walled structures through which bullets have traveled can lead to false trajectories owing to internal deflection. Inspection of all inner areas before accepting trajectories at "face value" is critical.

As already stated, at extended distances the investigator must take into account the true parabolic trajectory of bullets in flight by using appropriate ballistics software, as will be discussed in Chapter 17. The sole purpose of trajectory rods, real or "virtual," is to establish a path along which the shooter could have been positioned. This will mean that the shot could, theoretically, have come from anywhere between the point of impact of the bullet out to the point at which the line of sight terminates. This is illustrated in Diagram 6.4.

The use of trajectory rods alone can only propose an approximate shooter position. To be more specific, we need additional evidence such as footwear impressions, fired cartridge cases, cigarette butts, or other trace evidence. The combination of bullet trajectory and physical evidence can often considerably narrow down the possible shooter positions. For example, if we establish the probable general bullet trajectory and also have several fired

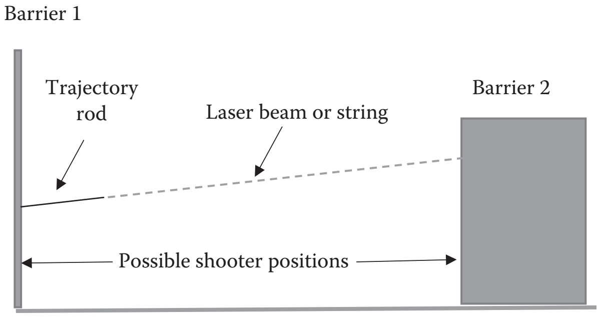

Diagram 6.4 Possible shooter positions.

cartridge cases at the scene, we have the ability to propose a probable shooter location. We begin by determining the ejection pattern characteristics for the weapon and ammunition (assuming appropriate conditions exist and we have other pertinent information—height/orientation of gun, etc.). Knowing the direction of the shot, we can determine approximately where along the trajectory path the shooter was positioned. Doing this also requires knowledge about the shooter height and shooting stance or making assumptions thereof.

Laser Measuring Devices

A number of laser measuring devices are available through various sources in addition to forensic suppliers. As might be expected, those with the "forensic label" tend to be more expensive, some justifiably so, some not so much. One of the author's colleagues advocates a unit that sells for about $150 through a major building supply retailer that he says is accurate, reliable, and carries a lifetime free replacement warranty (Kobalt, sold by Lowe's). The author has used a Leica Disto D330i (Figure 6.48) for the past year with excellent results. The unit is sold with red goggles that extend the visibility of the laser dot when used in bright sunlight. Of particular significance is the Bluetooth capability of this unit that allows measurements to be uploaded onto a smart phone, pad, or laptop for on-scene sketch preparation using the Leica Sketch App. The reader is encouraged to visit the following site for a demonstration of the device courtesy of AdvancedDimensions.com.

The Leica Disto D330i also calculates angles, heights, and square footage, and determines elevations and distances. The cost is approximately $400, but well worth it, in the

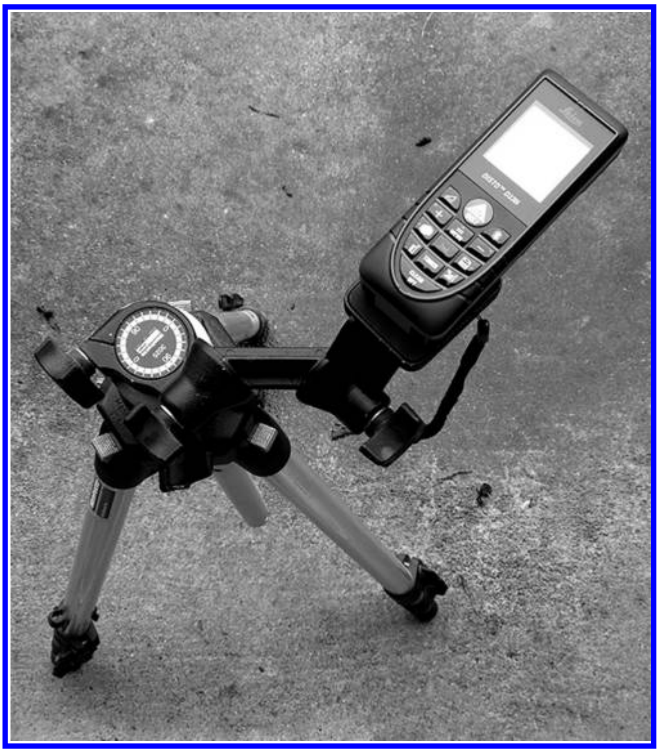

Figure 6.48 Leica Disto laser measuring device.

author's opinion, with an accuracy of ±1/16th of an inch out to 325 feet, and a tripod mount and built-in tilt sensor. For those interested in even more bells and whistles, they are available (www.leica-geosystems.com).

TRIPOD MOUNTED LASER AT THE UNIVERSITY OF TEXAS TOWER SHOOTING

Although compact, high-intensity lasers were not around in the 1960s. Having a tripod-mounted laser measuring device would have been very useful in documenting some of the shots fired during the Charles Whitman sniper incident at the University of Texas tower in the late 1960s. Numerous shots were fired up at Whitman from the ground by police and private citizens. The author was attending a summer session at the time of the incident and clearly remembers the bullet impacts into the face of the clock at the top of the tower. By setting up a tripod-mounted laser device on the ground below the tower, the height of bullet impact marks near the top of the tower could have been determined. Because the distance is more than 300 feet above the ground, other methods of measuring would have been more difficult to carry out. Similarly, a laser set up to approximate Whitman's field of view could have been used to determine downward angles for specific shots where victim locations were known.

Total Data Stations

The ultimate piece of equipment for shooting incident reconstruction has been the total data station. This device enables the acquisition of relative distance and position data of physical evidence and the subsequent downloading of these data into a computer software program for generation of a scale drawing. The total data station uses infrared light to accurately determine measurements from an established reference position. Total data stations can generate diagrams of buildings and vehicles as well as create general crime scene diagrams. Initially, because of their cost, they were out of reach for many small departments. Costs have come down considerably over the years, making them quite affordable.

3-D Laser Scanners

The use of 3-D laser scanners in surveying and engineering has been around for a number of years. 3-D laser scanning differs from total data station mapping in that there are no field notes in laser scanning, only data points. Also, there is no line of site with laser scanning, but a much more focused coverage. Consequently, huge data files result, requiring computers with significant data capacities for processing. This is a minor issue, given the quality of the results produced.

Michael G. Haag of the Albuquerque Police Department Crime Laboratory is one of the pioneers of the forensic use of 3-D laser scanners. In a 2008 presentation at the American Academy of Forensic Sciences Scientific Meeting in Washington, D.C., Mike and Leica Geosystems Forensic Account Manager Tony Grissom outlined the technique and how to apply it to shooting reconstruction.

A really impressive example of the forensic application of 3-D laser scanning was the work Mike and Tony did in their reconstruction of the 1963 assassination of President John F. Kennedy presented on the NOVA documentary on PBS, "Cold Case JFK." According to Mike, he and Tony spent an entire day at Dealey Plaza in Dallas collecting laser scan data. Mike graciously provided the following images of that work (Figures 6.49 and 6.50).

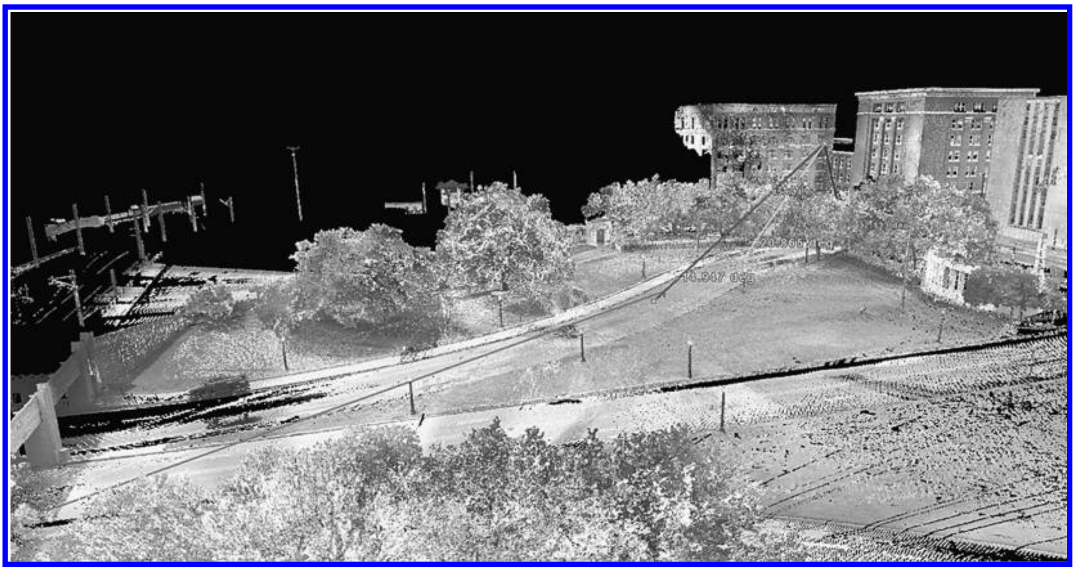

Figure 6.49 3-D laser scan of Dealey Plaza. (Courtesy of Michael Haag.)

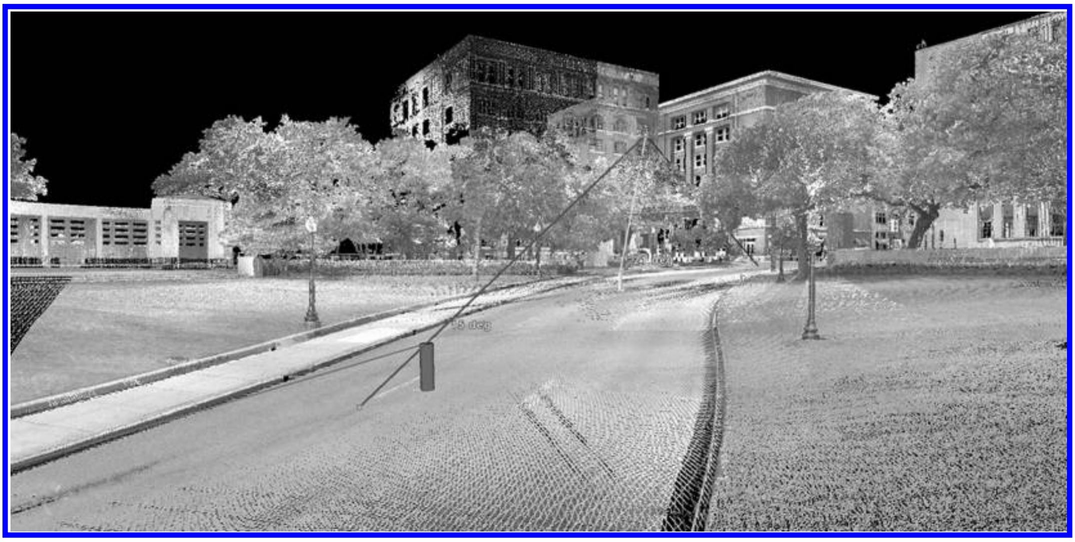

Figure 6.50 3-D laser scan of Dealey Plaza. (Courtesy of Michael Haag.)

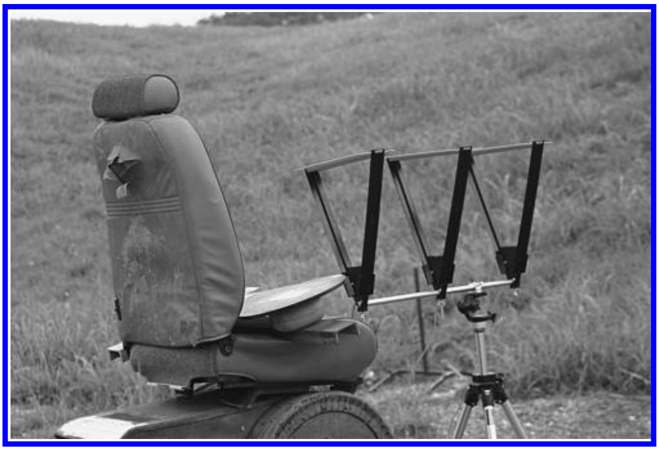

Figure 6.51 Chronograph with intermediary target.

Chronographs

Chronographs are used to determine muzzle velocities, velocities after passing through intermediary targets, velocities after ricochet, and various other projectile-related velocities. The use of a chronograph to determine the velocity of a bullet after first passing through a vehicle seat back is illustrated in Figure 6.51.

The chronograph measures velocities through the use of a series of "screens" through which bullets pass. As a bullet passes through the first screen, a beam of light is broken. Once the bullet passes through the last screen, a microchip calculates the elapsed time and converts it into feet per second.

AN EXAMPLE OF A CHRONOGRAPH BEING USED TO SOLVE A CASE

The author was involved in a case in which an individual had replaced the receiver cover of an AKS 7.62 × 39 semiautomatic rifle with an aftermarket receiver cover that was designed to accommodate a telescopic sight. The aftermarket receiver cover was made of cast iron rather than stamped steel like the original.

The owner took the rifle out to a shooting range in order to sight it in with the new telescopic sight. He purchased a case of Chinese-made ammunition to use for sighting it in and hunting. After successfully firing several rounds, a malfunction occurred that resulted in the front part of the aftermarket receiver cover flipping upward, carrying the telescopic sight along with it. The upward motion of the receiver cover and scope was as though the cover was hinged at the rear. This motion resulted in the eyepiece of the scope literally scooping the shooter's eye out. The receiver cover was cracked in the process. A search of the immediate area by investigators following the incident located a fired cartridge case with a deformed mouth. Rather than the bottleneck shape that should have been present, the mouth of the cartridge case was bulged out (see Figure 6.52). The head of the cartridge case was deformed as well with a portion missing from the rim (see Figure 6.53).

The question was whether or not the receiver cover was at fault. The focus was placed on the cover, naturally, because it was a nonfactory add-on. However, the receiver cover

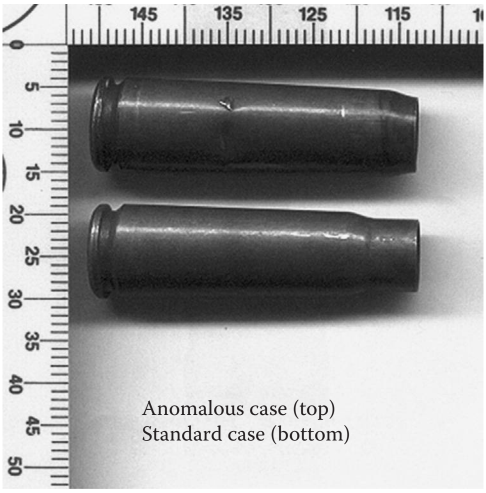

Figure 6.52 Deformed cartridge case (top).

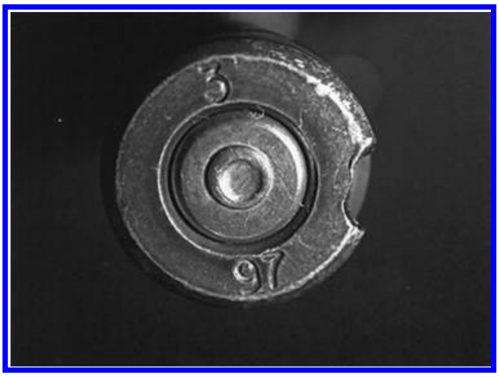

Figure 6.53 Deformed 7.62 × 39 head.

manufacturer was quick to point out that in thousands of such items, their company had never experienced a single failure and that their product exceeded the factory version in tensile strength even though it was a casting.

The damage to the receiver cover and the deformed cartridge case found at the scene indicated excessive pressure was involved. The focus of attention then became the ammunition. The question was whether the rounds were consistent in powder charge, bullet seating/crimping, primer seating, and cartridge case construction. The answer to the bulk of the questions lay in test firing representative samples from the case the victim had purchased. Any discrepancies of even a moderate nature would show up in the form of muzzle velocity variations. This was clearly a case for chronograph testing.

Three cartridges were selected from each box of 20 rounds contained in the case of 500 rounds. Comparison firing was also conducted on several rounds of U.S.-manufactured ammunition and also ammunition of Russian manufacture. For each group of three rounds, the chronograph determines the high, low, and average muzzle velocity and calculates the standard deviation. This allows the shooter to ascertain how close the loads are to one another and whether there are any "hot" loads involved that might result in higher than normal pressure.

As a result of the testing with a chronograph, the author was able to eliminate the ammunition as being the source of the malfunction. Ultimately, the culprit was determined to be the result of internal residual cosmolene (heavy grease applied for shipping to inhibit rust), causing the gas piston to stick and resulting in the weapon firing out of battery. By not being fully locked up, the bolt moved rearward with such force that the receiver cover was fractured and flipped up at the front producing the injury to the shooter.

Specialized Fixtures for Shooting Reconstruction

There are a number of specialized fixtures that are useful for helping to solve shooting reconstruction problems. Some of these fixtures are commercially available, but most of them are the product of "backyard ingenuity." With regard to commercial products, gun rests and gun holders come to mind immediately. The so-called machine rests, such as the Ransom Rest©, for handguns and long guns, have been around for many years and are well known to gunsmiths (Figure 6.54). By using a machine rest and a mechanical trigger release, a handgun or a long gun may be sighted in without having to deal with the "human factor" involved in holding and firing a weapon. A shooting table on which to mount the rests is essential to reproducibility. The shooting table was constructed by the author and is designed for easy disassembly to facilitate portability. The "C" clamps shown in Figure 6.55 allow quick removal of the Ransom Rest for transport and/or use of a long gun rest (Figures 6.56 and 6.57).

It is not uncommon for the accuracy of a weapon to be an issue in a shooting incident. The question as to whether the shot was intentional can come down to the weapon itself and how it was sighted in. This is particularly true when the weapon has a telescopic sight. The use of a machine rest is a requirement in such cases. This topic will be examined in more detail in Chapter 10.

A cardinal rule in shooting reconstruction is that theories must be subjected to physical testing. It is never adequate to rely on the theoretical concept without ever testing it. Thus, if an angle of impact, for example, is calculated by measuring hole width and length,

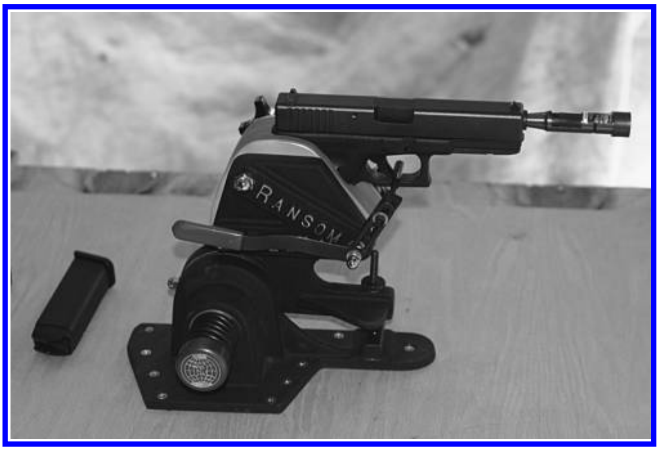

Figure 6.54 Ransom Rest.

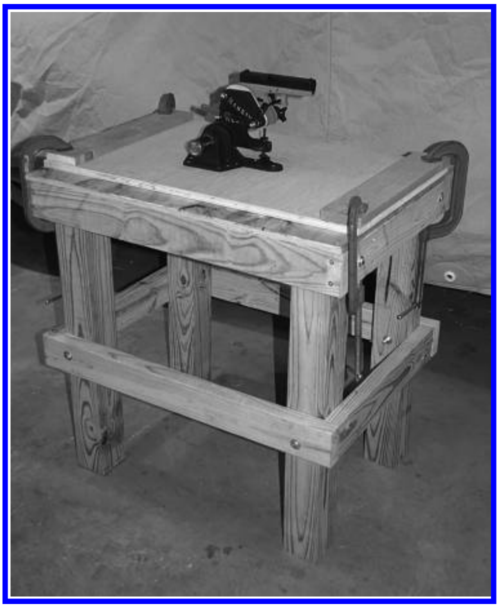

Figure 6.55 Shooting table with Ransom Rest.

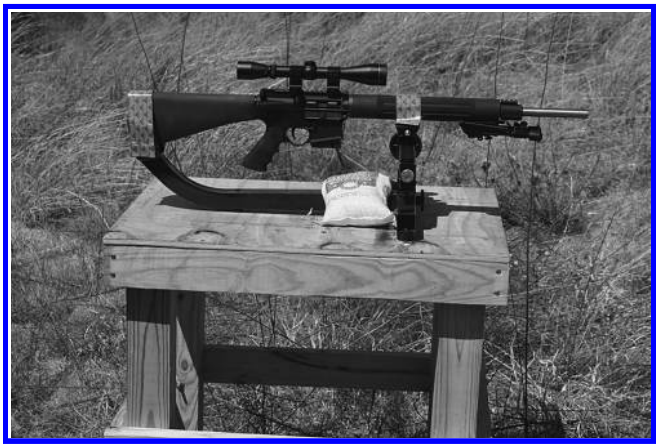

Figure 6.56 Shooting table with rifle rest.

the angle must be verified by test firing into the same or similar substrate using the same weapon and ammunition like that used in the actual shooting.

When it comes to setting up a target for impact angle verification, it is usually simpler to maintain the weapon in a rest at 90° to the front edge of the target base and then rotate the target to the desired angle rather than trying to adjust the angular orientation of the weapon to a fixed target. An example of an easily constructed target table with a rotating face is shown in Figure 6.57. The base consists of steel pipe to which a piece of 2 × 12-inch board has been bolted to serve as a mounting table for the target holder. The target holder is constructed of 2 × 4-inch boards glued and screwed together in a “U” shape. The bottom piece has a 1/4-inch hole drilled in the center as does the mounting table. A 1/4-inch bolt goes through the respective holes, and these parts of the apparatus are held together by the

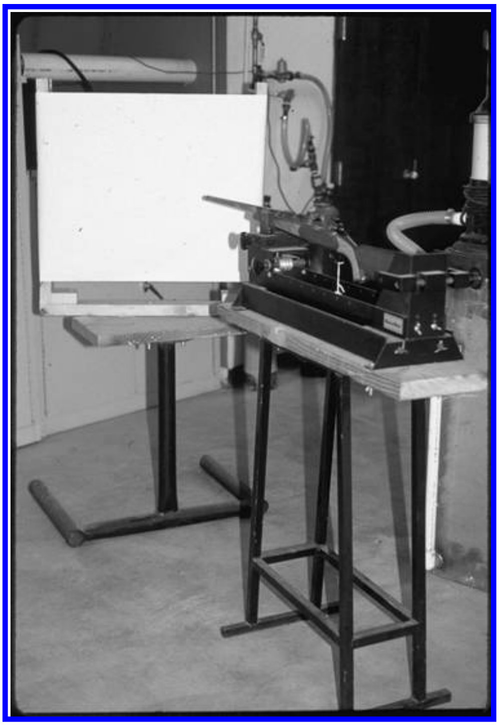

Figure 6.57 Rotatable target fixture.

bolt using a wing nut on the bottom. By loosening the wing nut, the target holder may be rotated as desired. The tabletop has been marked off in degrees to simplify angle settings. This device can accommodate fairly large target items.

A SHOOTING RECONSTRUCTION USING A SPECIAL FIXTURE

The author worked on the reconstruction of a shooting incident a number of years ago in which a bullet had passed through the rocker molding below the driver door on a vehicle in which the driver was shot to death. It was critical to the case to be able to establish the trajectory of the bullet that had passed through the rocker molding. The vehicle had been traveling along a roadway when the shooting took place. Because roads are sloped from the center to both sides for drainage, the position of the vehicle on the roadway could result in a slight difference in trajectory. The bullet trajectory needed to be determined as accurately as possible in order to determine if the defendant's version of events could be corroborated or not.

The first thought was to reenact the shooting by taking the vehicle back to the scene. However, the vehicle was no longer running and the thought of moving it about by hand did not seem too exciting given the fact that temperatures were in the nineties at the time. Because the rocker molding was removable, it was decided to construct a fixture that would support the rocker molding at the same height above the ground as when it was on the vehicle and use a laser to determine trajectory.

The first effort at constructing a fixture was somewhat reminiscent of a four-poster bed frame. The idea was to have the outer dimensions of the frame equivalent to the outer perimeter of the vehicle so spatial orientation could be visualized. The molding was attached to one side of the rectangle that had been created. As the crime scene was

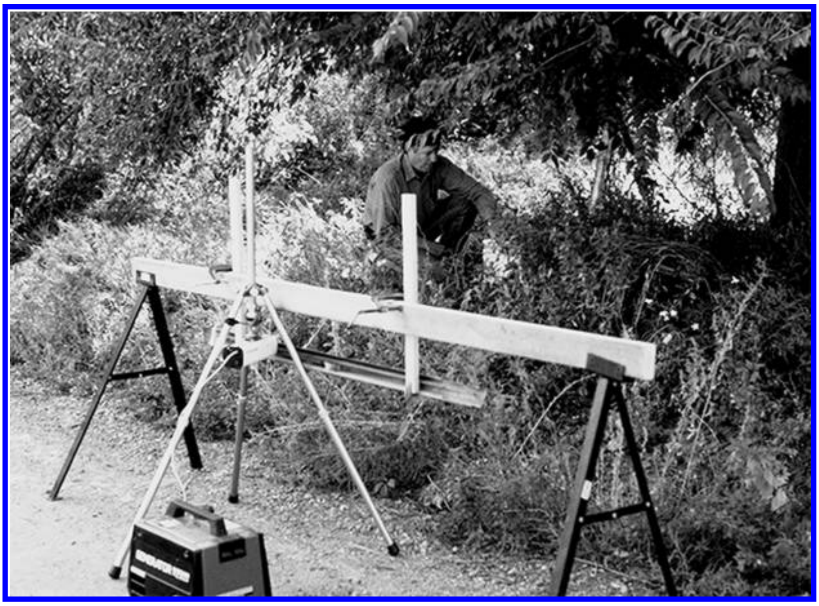

Figure 6.58 A special fixture for reconstructing a shot through rocker molding.

some distance away, the fixture had to be easily disassembled for transport. This necessity resulted in a rather rickety setup. Ultimately, it was decided to scrap the frame in favor of a much simpler and more easily moved fixture. The fixture that was devised consisted simply of a sawhorse that supported the rocker molding by using C clamps and pieces of 1 × 2-inch wood. Small pylons were used to indicate the points where each tire touched the ground. This gave a visual indication of the spatial orientation of the vehicle. The device was entirely portable and easily moved about on the roadway at the scene for testing the effect on trajectory of various possible positions. A laser was placed behind the rocker molding and projected through a piece of steel tubing that had been inserted into the bullet hole. The fixture being used at the shooting scene is shown in Figure 6.58. The fixture allowed the author to determine that the shot came from near the ground as opposed to being fired from an upright (i.e., standing) position. It should be pointed out that this contradicted a reconstruction by another expert who had tied a string to the end of a trajectory rod inserted into the molding while still on the Jeep. Given that the distance of the shot was approximately 50 feet, the difficulty of maintaining a string in exact alignment with the rod should be apparent, and the results obtained using a string rather than a laser reflect that.

Camera Equipment for Shooting Reconstruction

The proper documentation of a shooting reconstruction requires some specialized camera equipment in addition to basic crime scene photographic equipment. The following list covers both categories of photographic equipment:

- Single lens reflex digital camera (SLRD) with detachable flash (fixed flash only cameras are *not suitable*)
- Ring flash for macro photography

- A 6-foot sync cord (or wireless remote flash capability)
- Multiple lenses (e.g., 50 mm, wide angle, macro, and telephoto)
- Remote shutter release (wired or wireless)
- Tripod with reversible center and boom
- A variety of scales
- Flat black poster paper (to use as a background for glass windows, windshields, etc.)
- A black golf course–type umbrella (for blocking out the sun when necessary)

Some of the necessary equipment items are shown in Figures 6.59 through 6.63.

The rules for shooting reconstruction photography are similar to those for general crime scene photography with a few exceptions:

- Photographs should go from general to specific in three stages (i.e., distant, intermediate, and close-up views).
- Photographs should include both as is (no markers, scales, etc.) images and images with markers, scales, and other identifiers.
- Include orientation identifiers (e.g., door handles, keyholes) whenever feasible.
- Photographs of trajectory rods in place MUST include a side view and an overhead (or from below) view.
- The camera back should be in a plane parallel to the item of interest.
- Fill the frame with the object of interest.
- Use a tripod, remote shutter release, and ring flash when taking macro images.
- Practice special techniques before applying them at crime scenes.
- More is always better than less when it comes to the number of images taken.

Examples of representative photographs are shown in Figures 6.63 through 6.66.

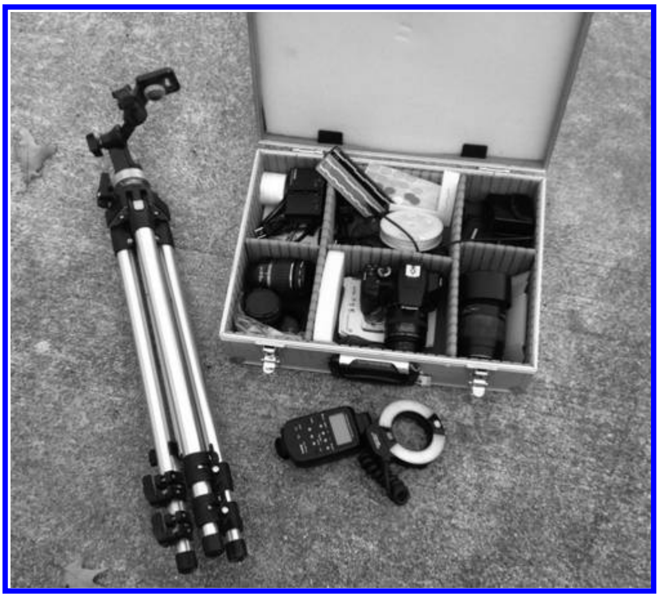

Figure 6.59 Basic photographic equipment needed.

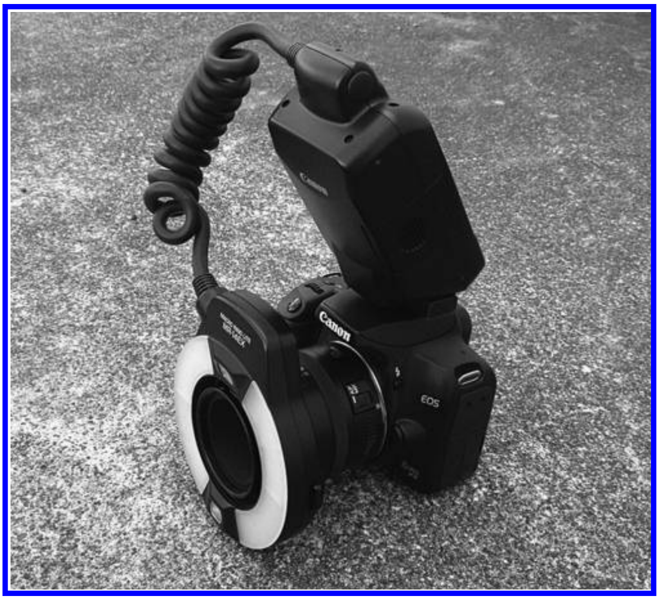

Figure 6.60 SLRD camera with ring flash.

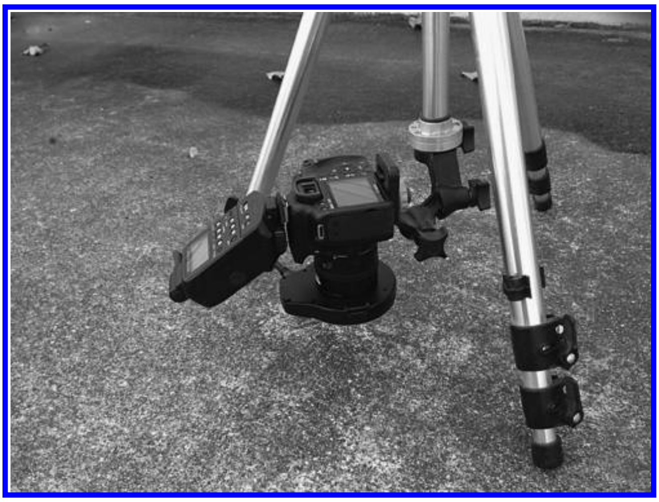

Figure 6.61 SLRD camera with ring flash mounted on reversed center of tripod.

Exercises

1. Which one of the following can be used as a trajectory rod?
    a. Fiberglass tent pole
    b. Steel rod
    c. Wooden dowel
    d. All of the above

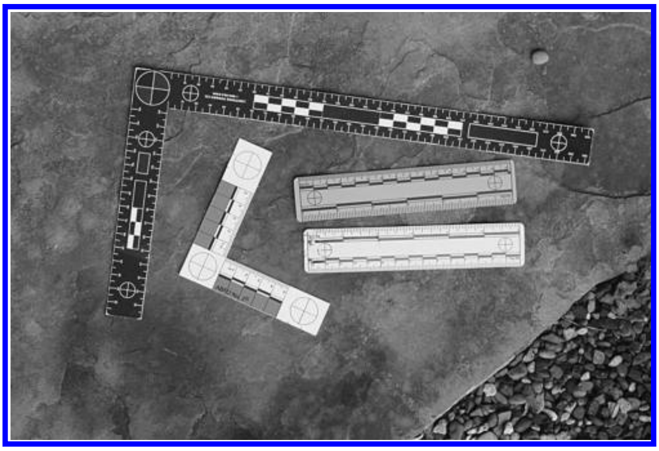

Figure 6.62 Various scales required.

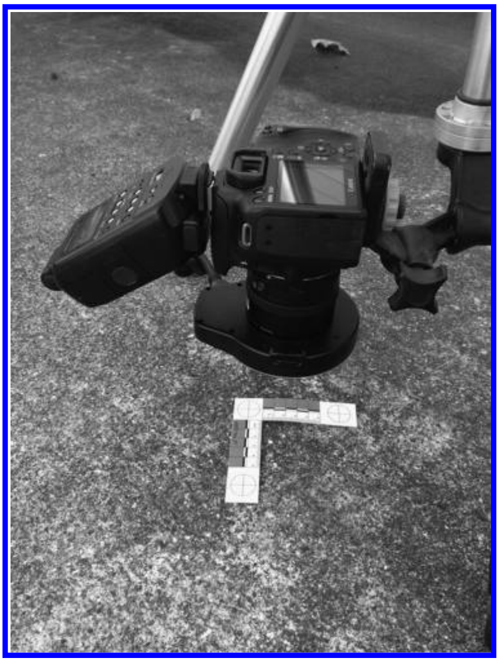

Figure 6.63 Scale in place.

2. Which one of the following is used when trajectory rods are placed into oversized holes?
   a. Pointed end
   b. Connector
   c. String connector
   d. Centering cone
3. Bullet holes through automobile sheet metal are often
   a. Smaller than the bullet
   b. Larger than the bullet
   c. About the same size as the bullet
   d. Indeterminate

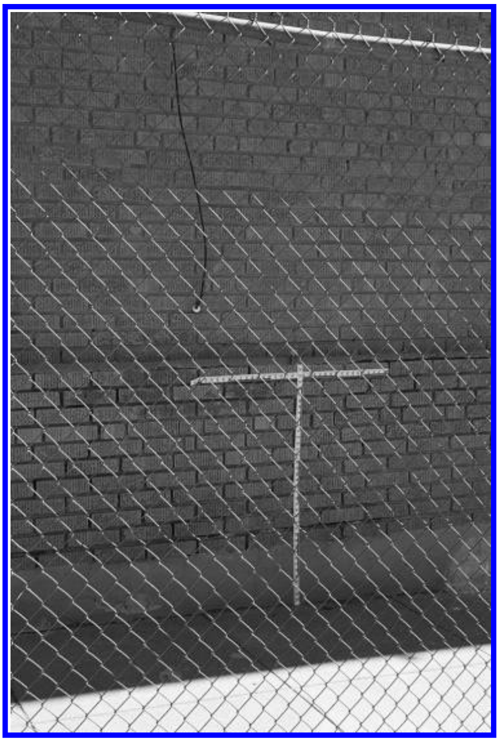

Figure 6.64 Distant photo of bullet impact (with scale).

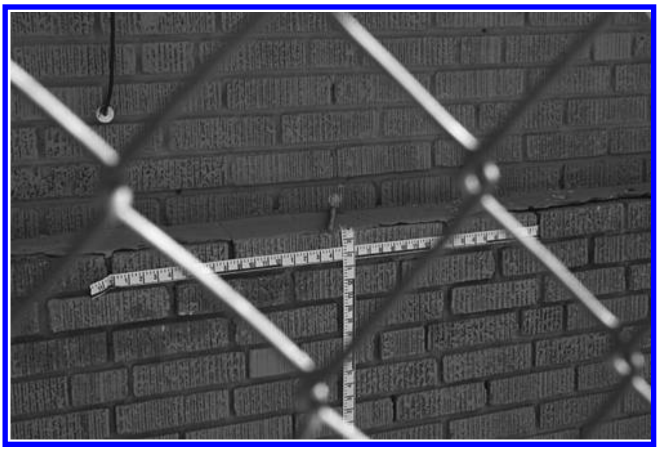

Figure 6.65 Intermediate photo of bullet impact (with scale).

4. The angle of impact for a bullet hole
   a. May only be measured with a protractor
   b. Can only be calculated by measuring
   c. Can be either measured with a protractor or calculated
   d. Cannot be determined
5. Trajectory rods work best with
   a. Double-walled materials
   b. Thin sheet metal

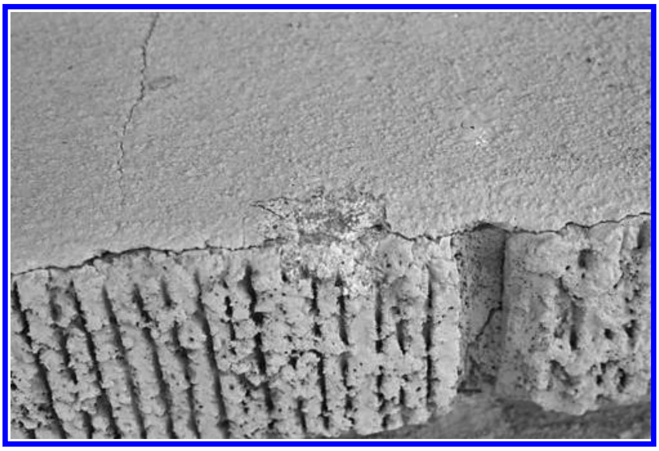

Figure 6.66 Close-up of bullet impact (without scale).

   c. Glass
   d. Most any material
6. Laser protractors are often used with
   a. Double-walled materials
   b. Thin sheet metal
   c. Glass
   d. Wood
7. Trajectory rods are used to
   a. Approximate the shooter's position
   b. Pinpoint exact shooter position
   c. Locate bullets
   d. Find trace evidence
8. The area where a bullet first passes through sheet metal at an angle of less than 90° is known as the
   a. Foot
   b. Face
   c. Shoulder
   d. Eye
9. Trajectory rod diameter
   a. Is unimportant
   b. Must be exactly the same as the hole diameter
   c. Should include an assortment of different diameters from 0.22 inch up to 0.50 inch usually
   d. Needs to be about 0.25 inch
10. When making angular determinations from irregular contours such as car doors, it is best to
   a. Approximate
   b. Use an angle gauge
   c. Use a plumb bob
   d. Use a zero base protractor

11. As bullet impact angle gets smaller, the bullet hole tends to
    a. Stay the same
    b. Get longer
    c. Get shorter
    d. Get wider
12. A trajectory rod placed through a bullet path will have
    a. Two angular components
    b. One angular component
    c. Three angular components
    d. No angular components
13. A trajectory rod placed through a bullet path will have
    a. Two-dimensional components
    b. Three-dimensional components
    c. One-dimensional component
    d. No dimensional component
14. Bullet holes striking a surface at about 90° tend to produce holes that are
    a. Irregular
    b. Elliptical
    c. Circular
    d. Oblong
15. Bullet holes produced by impacts at less than 90° tend to be
    a. Round
    b. Oblong
    c. Irregular
    d. Square
16. The trigonometric function that relates the impact angle to the width and length of a bullet hole is the
    a. Cosine
    b. Tangent
    c. Sine
    d. Pythagorean theorem
17. The angle of impact of a bullet hole is found by determining
    a. The arc sin of width/length
    b. The tan of width/length
    c. The arc cos of length/width
    d. The cos of width/length
18. The margins of a bullet hole should be examined for
    a. Blood
    b. Hair
    c. Fibers
    d. All of the above
19. Using a plumb bob to measure angles allows
    a. The use of only one hand
    b. The opportunity to photograph
    c. A common point of reference
    d. One person to complete the work

20. The use of a laser protractor is important when
    a. Thin, single-walled material is involved
    b. The hole is oversized
    c. There is a double wall
    d. The bullet cannot be found
21. Why are photographs taken before adding markers, scales, etc.?
    a. To completely document the condition of the substrate
    b. To have a backup for each image
    c. To allow for changing markers if needed
    d. Because it has always been done that way

    Answers: (1) d, (2) d, (3) b, (4) c, (5) a, (6) b, (7) a, (8) c, (9) c, (10) c, (11) b, (12) a, (13) a, (14) c, (15) b, (16) c, (17) a, (18) d, (19) c, (20) a, (21) a

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Smart Phone/Pad Apps for Shooting Reconstruction

7

The proliferation of cellular phones and the concurrent development of applications ("apps") has made its way into the realm of shooting incident reconstruction quite effectively. Many of the so-called apps mimic, to some degree, high dollar devices that were out of reach for many police departments. Other apps provide handy alternatives to the need to transport infrequently used equipment items. However, before "junking" all the traditional equipment items in favor of an "all-in-one" approach with a "smart phone," one must be aware of the fact that any app used for data acquisition at a crime scene or for a reconstruction must be calibrated against a known standard prior to its use. The calibration for a few of the apps will be illustrated and/or discussed in the context of their presentations within this chapter. An additional concern might be that the phone would be subpoenaed by the opposing counsel, although no instances of that have been documented to the author's knowledge.

Plumb Bob App

When determining trajectory rod angles of inclination/declination (i.e., the *y* angle) where there is no available vertical reference line (e.g., curved or irregular contour such as a car body), it is essential that a common reference line be established using a plumb bob. With a plumb bob, a perpendicular to the center of the earth becomes the reference line. There are several available apps that provide electronic plumb lines. One relatively simplistic and useful app is "PlumbBob" by appsamuck (free). The "calibration" of a plumb bob app is carried out by simply holding the phone next to an actual plumb line to show the correspondence. The use of the plumb bob app is illustrated in Figure 7.1.

The phone with the plumb bob app is being held against the base of a zero base protractor such that the base is parallel with the plumb line. Accordingly, each trajectory rod *y* angle may then be measured relative to a plumb line (the common reference). With this app, as long as you have your phone and it is adequately charged, you always have a plumb bob at the ready.

Compass App

A compass should be a part of every crime scene kit for the purpose of defining orientation both of and within a scene. Such orientations are best obtained using a compass. Although most compasses show basic direction based on magnetic north, compass apps also include digital coordinates as shown in Figure 7.2. If all you wish is establishing

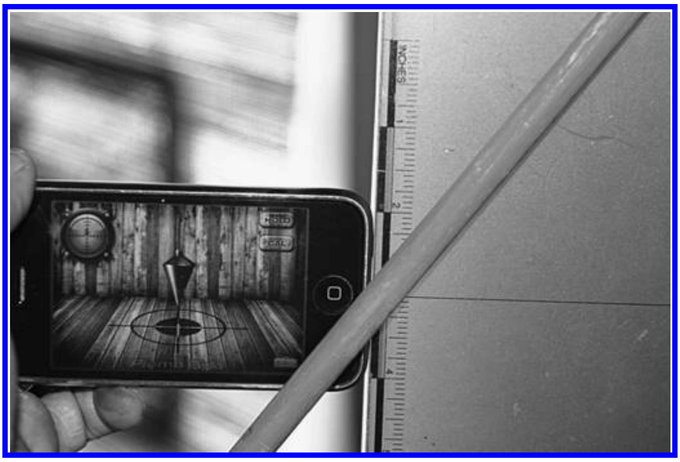


Figure 7.1 Plumb bob app.

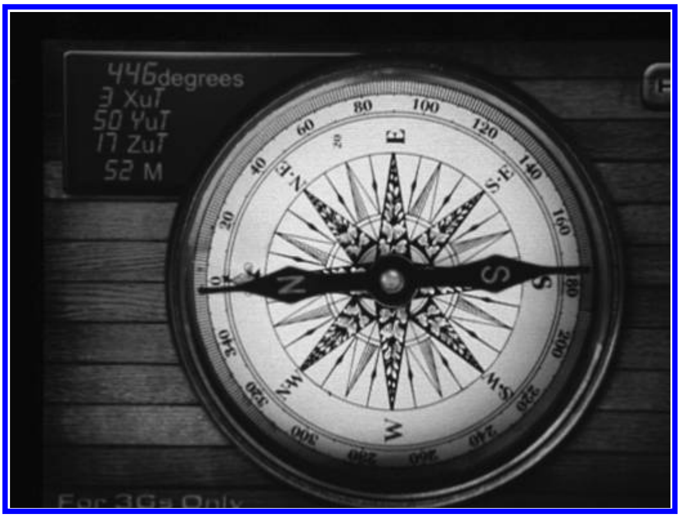


Figure 7.2 Compass app.

basic directionality, Tim O's Studios free Compass app may fit your needs. The only thing that appears on the screen is a large letter—N, S, E, or W—along with the heading (in degrees).

Calibration may be simply accomplished with a standard compass.

Angle Gauge App

Several angle gauge apps are available, and although many are free, self-contained ads require kicking in $0.99 to be removed (Figure 7.3). If the ads do not bother you, then free really is free! Once again, calibration against a known standard (e.g., a protractor) should be done before accepting results at face value.

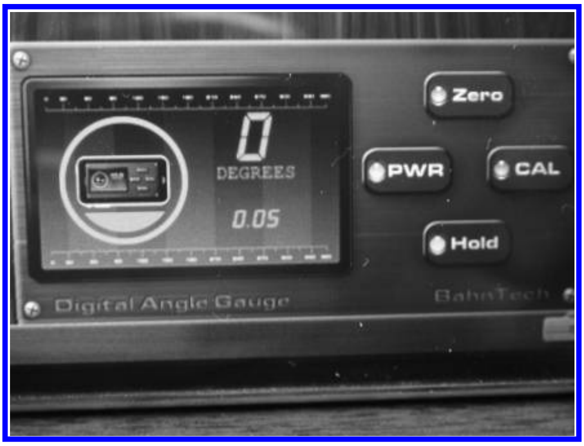


Figure 7.3 Angle gauge app.

Scientific Calculator App

The calculation of impact angles and other mathematical operations used in solving shooting reconstruction problems require the use of trigonometric functions (sine, cosine, tangent, etc.). In the event that your smart phone or pad does not come preloaded with a scientific calculator, one can be easily had from a number of different suppliers for literally little or nothing. Years ago, it was actually the scientific calculator that was the first app that got the author started on using apps in shooting reconstruction.

Level App

A level app is particularly useful when taking photographs where it is essential that the camera be positioned on a plane that is parallel to the substrate being photographed (i.e., to minimize distortion in the photograph) (Figure 7.4). Calibration can be carried out using a traditional bubble level although the level app is probably not going to have much potential for challenge.

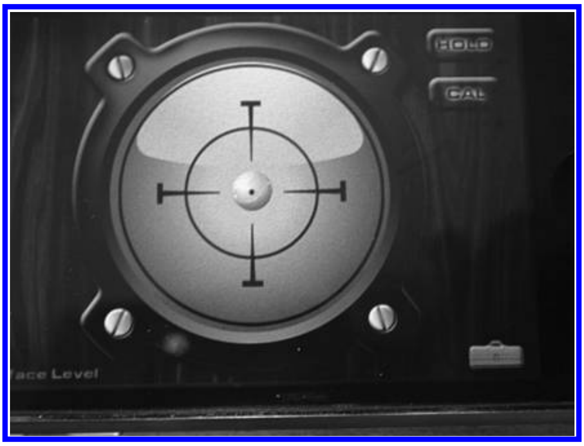
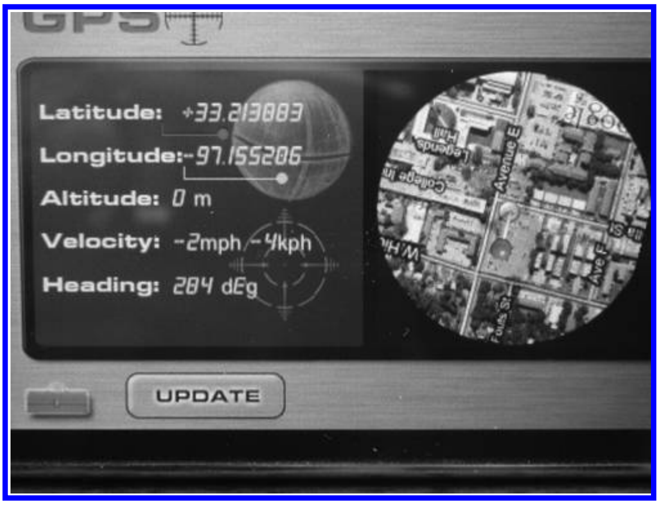


Figure 7.4 Level app.

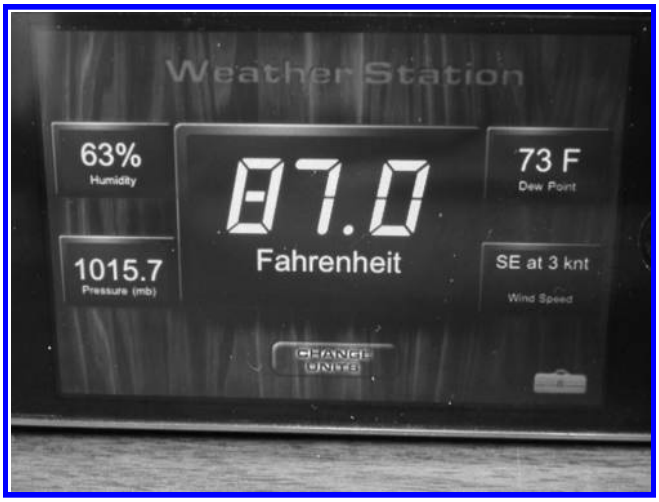
Global Positioning System App

Real-time global positioning system (GPS) can provide an iPhone or Android device with the same capabilities as a stand-alone navigation system. This can be used to establish such things as possible routes between locations in crime scenes having multiple sites and also to determine approximate travel times as part of case analysis. The use of GPS is particularly helpful in remote locations for providing longitude and latitude coordinates (Figure 7.5). An added plus is the provision of climatic conditions. It must be remembered that the climatic conditions being provided apply to outdoors only. Things such as indoor temperature and wind speed obviously do not apply. There are a number of free GPS apps, such as Mapquest, that are available. Weather station apps themselves are readily available with the same restriction (i.e., outdoor conditions only) (Figure 7.6).



Latitude: +33.213083
Longitude:-97.155206
Altitude: 0 m
Velocity: -2mph -4kph
Heading: 284 dEg

Figure 7.5 GPS app.



63% Humidity
87.0 Fahrenheit
73 F Dew Point
1015.7 Pressure (mb)
SE at 3 knt Wind Speed

Figure 7.6 Weather station app.

Measuring Apps

A number of apps are available that offer various types of measuring capabilities including both linear and angular. Virtual caliper apps are useful for measuring fired bullet diameters but require both handling of the evidence and placing it on the screen of the phone, both of which may not be acceptable under many conditions (e.g., bullets with biological contamination) (Figures 7.7 through 7.9). It should be pointed out that these and many of the other apps are not intended to replace conventional crime scene equipment but merely offer a backup or alternative as the need arises.

Angle Meter© is a free app that uses the body of the phone or pad to make angle measurements. It is simple to use and works well. Easy Measure© is an app that uses trigonometry and the built-in camera to calculate distances and record images (Figure 7.10). A data sheet is generated (a comma-separated text file) that can be e-mailed. The images may also

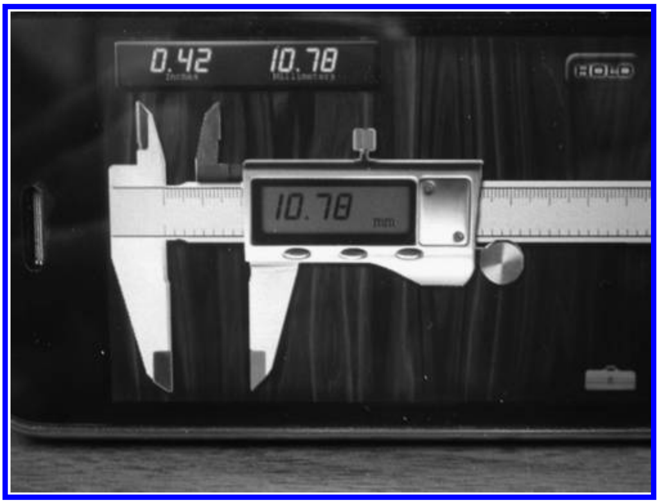


Figure 7.7 Caliper app.

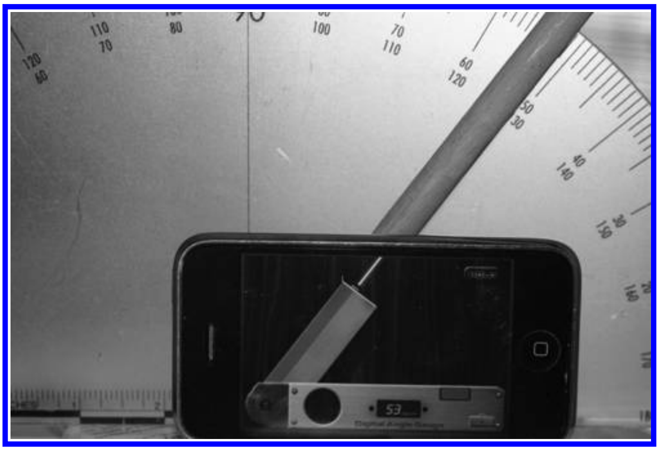


Figure 7.8 Virtual laser protractor app (shown being calibrated).

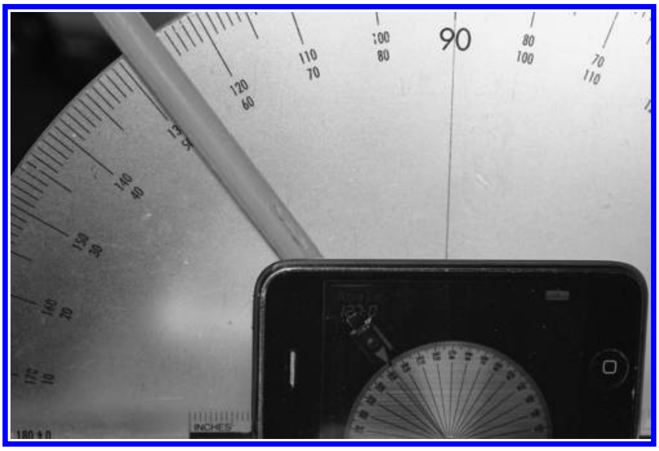

90
80
100
70
110
110
70
100
80
120
60
140
40
150
30
160
20
170
10
180 ± 0
INCHES

Figure 7.9 Virtual standard protractor app (shown being calibrated).

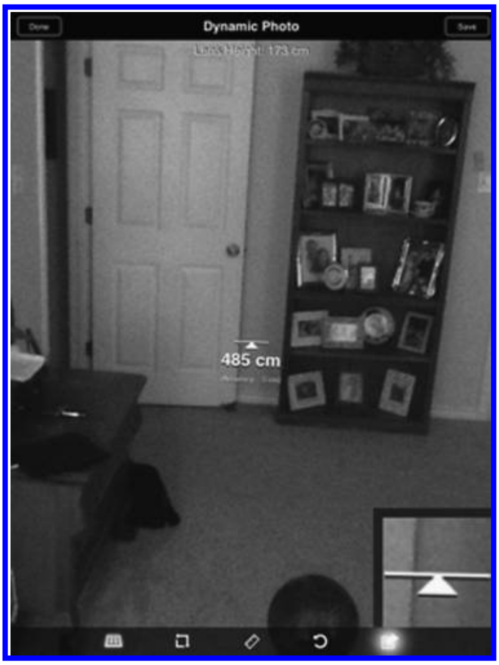

Done
Dynamic Photo
Save
Lens Height: 173 cm
485 cm

Figure 7.10 Easy Measure image showing measurement to a point on the wall.

be messaged or e-mailed out. Accuracy leaves a bit to be desired with distances of 8 feet being given + or −6 inches for example.

The ultimate in measuring apps is Theodolite by Hunter Research and Technology. This app provides incredible technology for distance and angle measurement for a mere $3.99. The Hunter description posted on their website is spot on:

> Ability to take geo-stamped and geo-tagged photos and screenshots from the app, with 2× and 4× zoom, buffered background image saves, plus an option to write custom notes on photos. Integrated map with standard, satellite, and hybrid views, compass rose, and bearings. Ability to manage location markers on the map. Optical–mechanical gyro/accelerometer

> calibration. Zero angle reference mode. A–B survey calculator for height, distance, heading, position and angles. Data logging. E-mail data export with KML. Clipboard integration. Percent Grade. Optical rangefinders. Mils. Night vision lens filters. MGRS, UTM, and four lat/lon formats.

The only requirement for the maximum utility of this highly sophisticated app is a fixed position (i.e., tripod) mount. The author fabricated such a mount using readily available materials as shown in Figures 7.11 and 7.12.

Images are readily available and are stamped with all the specific location and other data as shown in Figure 7.13.

An extremely important accompanying app is the Theodolite User Manual (Figure 7.14), which is also available through Hunter Research and Technology. This manual provides clear instructional information for using the Theodolite app (Figure 7.15). There is certainly a rather significant learning curve with this app and a great deal of stress relief is offered via the user manual (Figure 7.16). The manual can, of course, be printed for those of us still stuck in the 1980s, but having it loaded on the phone or pad means it is always

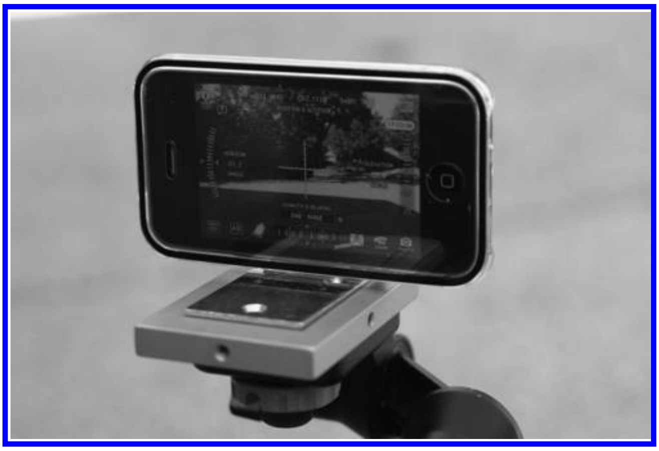


Figure 7.11 Theodolite app used with fabricated tripod mount for iPhone.

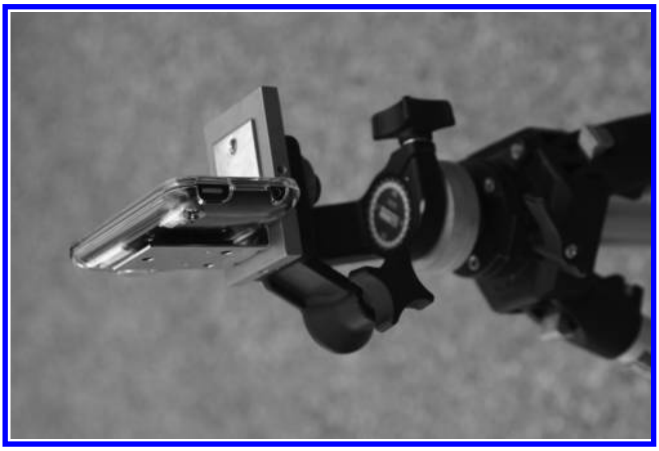


Figure 7.12 Tripod mount (fabricated) for iPhone Theodolite use.

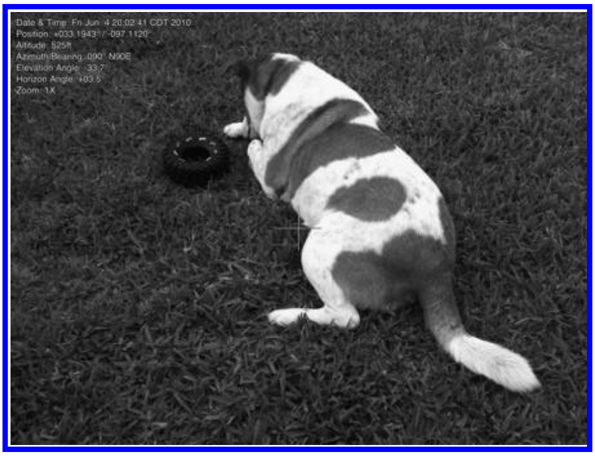

Date & Time: Fri Jun 4 20:02:41 CDT 2010
Position: +033.1943° / -097.1120°
Altitude: 525ft
Azimuth/Bearing: 090° N90E
Elevation Angle: -33.7°
Horizon Angle: +03.5
Zoom: 1X

Figure 7.13 Image stamped with location data via Theodolite.

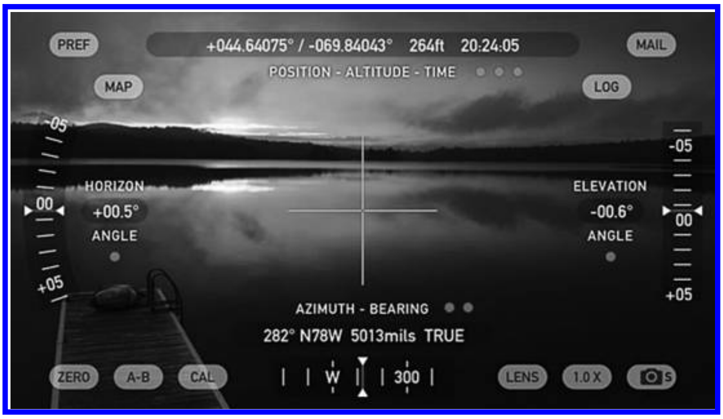

PREF
+044.64075° / -069.84043° 264ft 20:24:05
POSITION - ALTITUDE - TIME
MAIL
MAP
LOG
-05
00
+05
HORIZON
+00.5°
ANGLE
ELEVATION
-00.6°
ANGLE
-05
00
+05
AZIMUTH - BEARING
282° N78W 5013mils TRUE
ZERO
A-B
CAL
W
300
LENS
1.0 X
S

Figure 7.14 Theodolite screen.

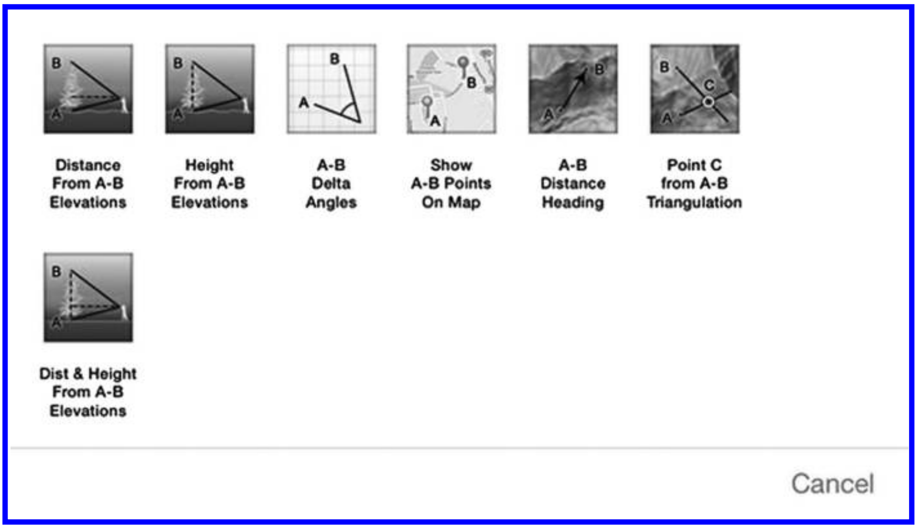
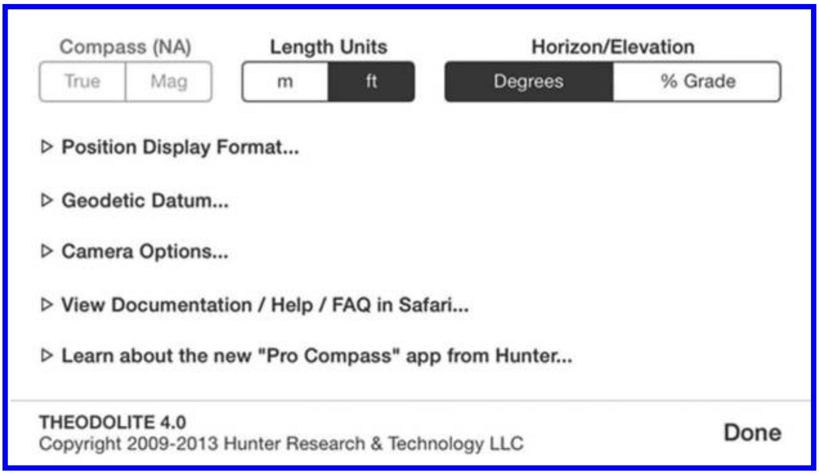

B
A
Distance From A-B Elevations
B
A
Height From A-B Elevations
B
A
A-B Delta Angles
B
A
Show A-B Points On Map
B
A
A-B Distance Heading
B
C
A
Point C from A-B Triangulation
B
A
Dist & Height From A-B Elevations
Cancel

Figure 7.15 Theodolite measuring capabilities.



Compass (NA) True Mag

Length Units m **ft**

Horizon/Elevation **Degrees** % Grade

▷ Position Display Format...

▷ Geodetic Datum...

▷ Camera Options...

▷ View Documentation / Help / FAQ in Safari...

▷ Learn about the new "Pro Compass" app from Hunter...

THEODOLITE 4.0
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Done

Figure 7.16 Theodolite preferences screen.

there (as long as there is power!). There is also online assistance available. If there was only one app allowed, Theodolite would be the author's choice above and away (as long as the user manual is also permissible!).

Flashlight App

The flashlight app, albeit a bit mundane to discuss this on the heels of the Theodolite app, is rather useful (if only utilitarian). Again, an app that lends itself to special situations, the most fundamental of which is the lack of any other alternative (Figure 7.17). There has been some Internet discussion of flashlight apps, particularly the free ones, being a conduit for all the information in one's phone or pad. No credible information has surfaced to the date of this writing. Perhaps the safeguard of paying rather than going for the free version provides at least some mental security.

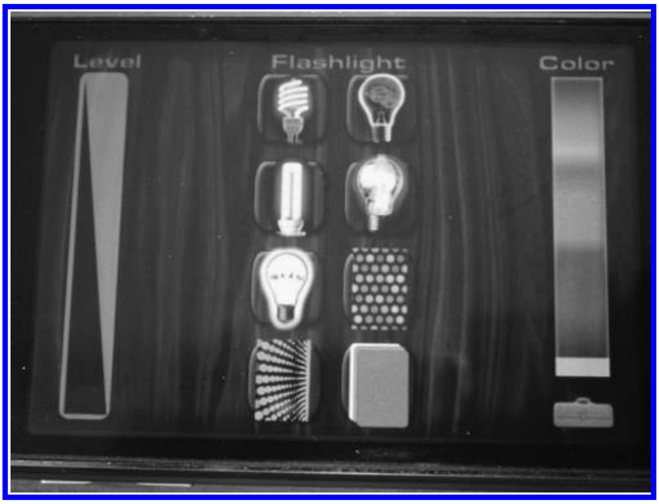


Figure 7.17 Flashlight app.

Other Useful Specialty Apps

The author has found a number of apps to be quite useful for evaluating and reconstructing shooting incidents. The following is a listing of some of those apps:

1. ATF's Police Officer's Guide to Recovered Firearms—This is a free app that provides useful information as to tracing firearms, nomenclature, and serial number location.
2. Texas Code of Criminal Procedure—This app is available for most states for a fee and provides a field reference to pertinent criminal procedure.
3. The Elements—This is an app by Touch Press that must be purchased as it has a "live action" version of the Periodic Table of the Elements showing properties, atomic structures, reaction characteristics, etc. Although primarily directed toward the chemist, laypersons may find some good information concerning specific elements that relate to shooting incidents (e.g., carbon, barium, antimony, and lead).
4. Winchester Ballistics—This app is free and provides some information of value relating to external ballistics (as long as it is Winchester ammunition that is involved).
5. Science Glossary @ Vision Learning—This is a free glossary of random terms frequently encountered in various fields of science (e.g., biology, chemistry, physics). Things that a layperson might not understand or be able to define are explained in a clear and concise manner (e.g., DNA, RNA, kinetic energy, genotype).
6. Visible Body® Atlas—This app costs approximately $30 but provides 3-D fully rotatable images of skeletal, musculature, arterial, etc., structures with full or partial body views. It is an excellent tool for tracing bullet trajectories as described in autopsy reports and for creating demonstrative exhibits. The image shown in Figure 7.18 was created using this app, and highlights the bones impacted by the bullet that struck the individual involved in a shooting incident (per the autopsy report).
7. Showmystreet.com—This free online service provides the ability to toggle back and forth between street view and satellite view.
8. Instant Google Street View—This free online service has inset satellite/map view as well as the main street view image.

One extremely important aspect of using the satellite and street view apps to review scenes is when the images were recorded. The author has had a number of occasions come up when the images showed an out-of-date scene that did not reflect the scene contemporaneously. Sometimes this is fairly easy to verify and other times not so much. The watchword is be careful when presenting images taken off the Internet as true and accurate of a given scene at a given point in time.

If you are using the Google Earth program, zoom in as much as possible. The capture date of that image should be visible in the status bar. If you are using Google Street View, you can use the Google Maps website to determine the scan date.

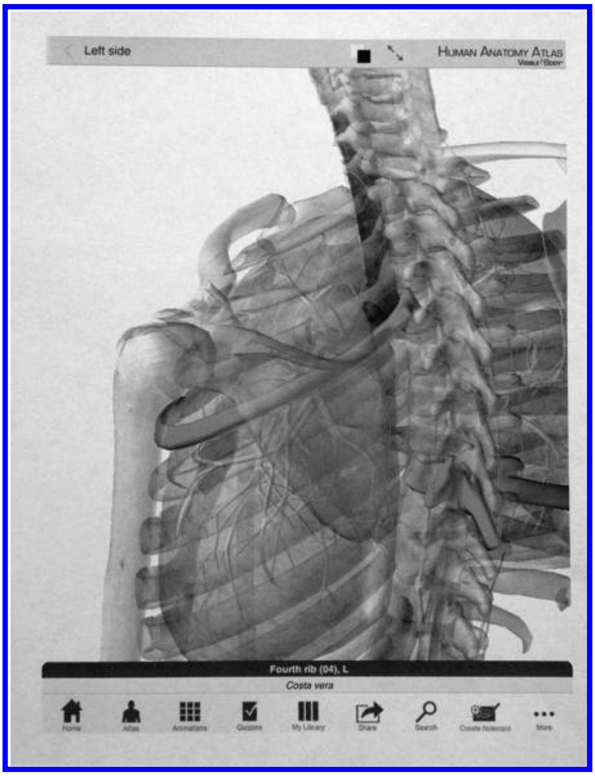


Figure 7.18 **(See color insert.)** Visible Body image (bones impacted by bullet in blue).

Other Visual Aids

Although they are not apps, surveillance videos have become commonplace in the review of shooting incidents. Surveillance cameras affixed to poles and other structures frequently can provide a 360° visibility of shooting incidents when used in combination. Likewise, dash cameras in police vehicles frequently provide useful information. The move to lapel cameras for all street officers is welcomed by most agencies and will no doubt be a useful adjunct to other video footage.

Interestingly, without audio (and sometimes with it), video footage does not always provide the answers sought in a shooting incident. In a police shooting case the author was involved in reconstructing a few years back, a dash camera in the patrol unit involved recorded much of the action leading up to and during the shooting. Unfortunately, the officer had not activated the audio on the camera. It was very difficult to determine not only when shots had been fired, but whether they impacted the suspect or not.

In summary, rapidly advancing technology is available and goes a long way in the effort to reconstruct a shooting. Individuals tasked with reconstruction should seek out this technology and become proficient with it. However, technology is not a panacea and cannot make up for sloppy or lackadaisical shooting scene evaluation and documentation. We must always bring our "A" game to each scene we are called upon to work.

Exercises

1. Go to Google Earth and find a location you are familiar with such as your residence. Once it has been found, zoom in and see if you can locate the scan date in the status bar of the image of that location.
2. Use two different search apps (e.g., Show My Street and Google Street View) to bring up the same location. What, if any, differences do you see?
3. Use two different satellite imaging programs to search for some location you are very familiar with. What, if any, differences can you detect?

Cartridge Case Ejection Pattern Testing for Semiautomatics

8

The mention of cartridge case ejection characteristics evokes an immediate negative response on the part of some individuals and sometimes for good reason. There are definite requirements as to when such testing is appropriate as well as how it should be carried out. When these requirements can be met, useful information may be obtained.

Testing Considerations

Under the right conditions, cartridge case locations can provide useful information as to the probable shooter position(s). A number of variables are associated with how a particular weapon ejects fired cartridge cases. These variables include:

- Weapon design
- Weapon condition
- Ammunition type
- Position weapon is held in when fired
- Movement of weapon during firing
- How tightly the weapon is held during firing
- Type of terrain shooting occurs on
- Presence of obstacles in the scene

A typical cartridge case ejection is shown in Figure 8.1.

What must be determined in a shooting incident in which there are ejected cartridge cases is how many of these variables are unknown and what effect, if any, might there be by not having information about those variables. For example, if fired cartridge cases are found at a shooting scene but no gun is recovered, no meaningful results can be obtained by carrying out cartridge case ejection testing with some weapon selected at random. Although it might be possible, from the markings left on the cartridge cases, to predict a possible weapon, tests must be carried out using the particular weapon and similar ammunition (i.e., from the same lot if possible).

Weapon design determines the general cartridge case ejection characteristics (i.e., rearward and to the right, forward, straight up). Unless the specific weapon that fired the cartridge cases can be identified, the ejection characteristics cannot be stated to any degree of certainty. Certainly, there can be physical evidence that supports only one general ejection characteristic, but those situations tend to be in the minority at shooting scenes.

The importance of using the same weapon for testing as that used in the shooting cannot be overemphasized. For example, variations in how clean and well lubricated the incident weapon was as compared to the weapon used for ejection pattern testing can have

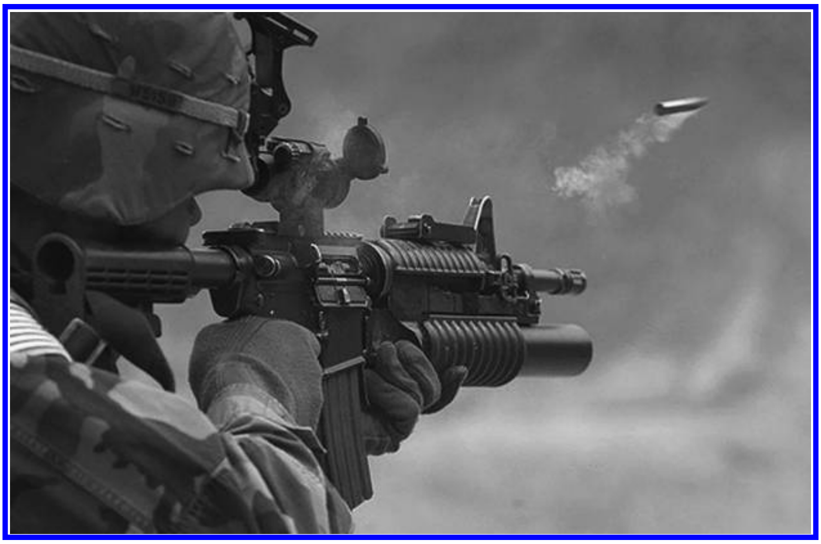


Figure 8.1 Cartridge case ejection.

a decided effect on cartridge case ejection even to the extent of resulting in failure to eject. Likewise, different spring pressures for recoil springs and magazine follower springs as found in different weapons of the same make and model can effect ejection.

Naturally, an argument might be made as far as possible differences in operability due to wear and tear when a significant length of time has passed since a shooting and when the suspect weapon is obtained. Nonetheless, using the same weapon for test firing is the appropriate way to go. If there is a legitimate question as to the state of cleanliness and lubrication of the weapon at the time of shooting versus as received for test firing, one can always test fire it as received and then clean and lubricate before retesting and comparing the results. Sometimes weapons are received with broken or missing parts. It is then necessary to repair/replace the parts in order to render the weapon operable. If the part or parts required could in any way effect cartridge case ejection, an appropriate disclaimer must be included in any subsequent report or testimony relating to the ejection pattern results.

Ammunition type can produce significantly different ejection patterns. There is a big difference, for example, in the ejection characteristics for a weapon firing standard loads versus the higher velocity “+P” and “+P+” loads owing to the increase in pressure associated with these loads. Even similar loads from the same manufacturer can have different powder types. The best bet is to use some of the same ammunition recovered with the weapon, if any is present. If not, and it is possible to determine the lot number from which the incident ammunition came, ammunition from the same lot is appropriate. If only the brand of ammunition is known, it is essential to ascertain what style and weight of bullet was involved in order to acquire similar factory loads. It is a good idea to pull the bullet from a round so that a determination of powder type may be made and compared to any powder from the victim/scene if available. In this way, it can at least be established that the same type powder is being used for test firing as was used in the incident.

Hand loads present a unique set of concerns. First and foremost, it must be established that the hand loads are consistent in powder charges, bullets, and primers. This can be established by disassembling several, if a sufficient number are available (they can always be reassembled and fired if need be). If there are a sufficient number, test firing and chronographing a few rounds can also provide the answer. Of course, if the ejection pattern developed through test firing is fairly consistent, the answer is self-evident: they are similar in makeup.

The position the weapon was held in at the time the shots were fired can have a drastic effect on cartridge case ejection pattern. The so-called “gangsta” style of holding a weapon sideways while firing produces an altogether different pattern/location than when the weapon is fired while being held in the traditional manner. Likewise, firing while the weapon in pointed downward produces decidedly different results than when firing with the barrel more or less parallel to the ground. The bottom line is that when there is verifiable information as to how a weapon was held during a shooting, it must be factored into the testing. This is most likely to be the case in officer-involved shootings where officers can provide details as to their shooting stance. In any event, weapon position is a definite consideration. In Figure 8.2, the shooter fired from a tactical position while standing at the intersection of two yellow measuring tapes that were laid on the ground. A total of six rounds were fired using a Glock .45 GAP pistol and .45 GAP duty ammunition. The ejected cartridge cases were designated by yellow markers. The cartridge case designations in the lower-right quadrant in Figure 8.2 resulted from a standard two-hand hold with the gun upright and fired parallel to the ground. The gun was next fired at a downward angle of approximately 30°, resulting in the ejected cartridge cases designated in the upper right quadrant. Finally, the gun was fired while being held sideways (i.e., “gangsta” style) with a right-hand hold, resulting in the ejected cartridge case designations in the lower left quadrant, as seen in Figure 8.2.

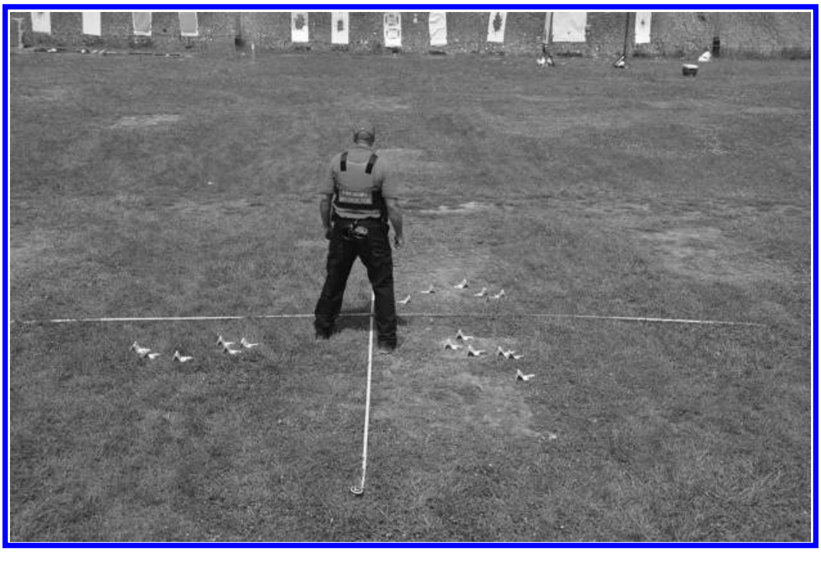


Figure 8.2 Ejection pattern change with firearm orientation change.

A CARTRIDGE CASE LOCATION RAISED A SERIOUS QUESTION

The author was involved in a case in which the question of how the shooting occurred was raised. According to one version (that of the survivor), the decedent was upright and lunged at the shooter who then shot the decedent in the chest. The decedent was said to have gone down to the ground, turning as he went and winding up on his back. The question was raised as to whether the shooter could have been standing at the decedent's head as he lay on the ground on his back, thus negating the self-defense aspect.

A single fired cartridge case was found to the decedent's right as he lay on the ground. The weapon and ammunition like that used in the shooting were obtained for use in test firing. The weapon was found to eject fired cartridge cases to the right rear of the shooter when the gun barrel was held parallel to the ground. The ground was relatively flat and covered with leaves. If it is assumed that the cartridge case location was pristine and representative of the actual point where it came to rest, the shooter could not have been facing the decedent as he stated.

On determination of the general ejection pattern characteristics, test firings were conducted with the gun barrel pointed downwards toward the ground. The gunshot residue pattern on the decedent's shirt indicated a muzzle-to-target distance of 12–24 inches. Using a distance of 18 inches from the muzzle to the ground, the cartridge cases were found to land in the same general area with respect to an imaginary body on the ground as at the scene.

The conclusion was that, based on cartridge case location at the scene, the shot was more likely fired while the decedent was on the ground rather than standing upright. This, again, can only be stated contingent on the cartridge case at the scene not having been moved and also the decedent not having been moved. Several individuals responding to the scene could corroborate the position of the decedent but only the crime scene investigator who found the fired cartridge case could speak about its position. Therefore, the disclaimer concerning the cartridge case location had to precede all discussion concerning its significance.

If a weapon is moved about as it is fired and/or the shooter changes positions, cartridge case locations will be affected accordingly. The usefulness of cartridge case locations under these conditions can be pretty limited unless there are bullet strikes that can be used to relate to the cartridge case locations. For example, let us say we have a weapon that ejects rearward and to the right when the weapon is held in the usual manner and with the barrel approximately parallel to the ground, and two shots are fired in directions approximately 90° apart and the fired cartridge cases stay pretty much where they first hit the ground. Using the weapon and ammunition recovered from the suspect, we establish an average ejection pattern of 20° rearward from the plane of the breech face of the weapon at a distance of 5 feet. If we have no information as to where the bullets struck, the locations of the two fired cartridge cases could indicate a shooter in any position 360° around the cartridge cases as shown in Figure 8.3.

On the other hand, if we have bullet strikes/holes at the scene that we can relate the cartridge case locations to, we can approximate the shooter positions using the average ejection angle and distance we determine through test firing. This is represented in Figure 8.4, where the arrows represent the bullet trajectories and the right triangles are based on a hypotenuse that corresponds to the average distance cartridge cases are ejected at an average angle from the plane of the breech face.

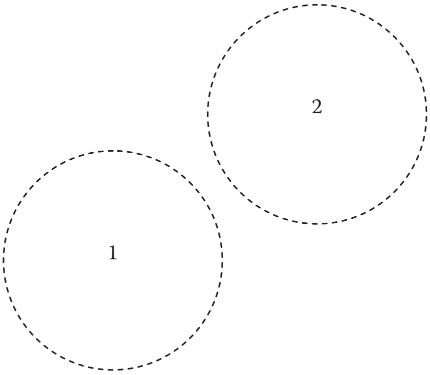


Figure 8.3 Possible shooter positions (dashed circles) based on cartridge case locations (1, 2) and average ejection distance.

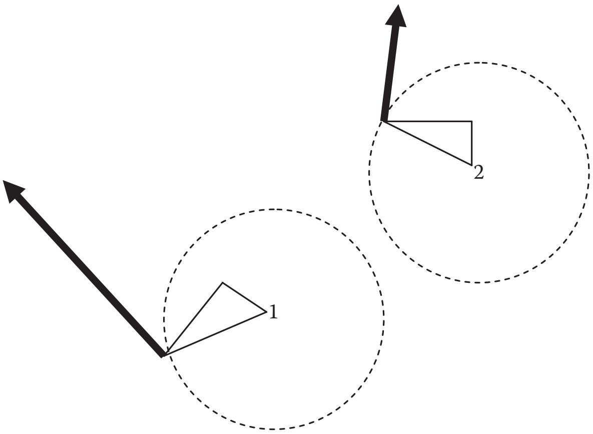


Figure 8.4 Approximate shooter positions based on locations of fired cartridge cases, bullet holes at scene, and average ejection angle and distance (assuming weapon is fired from a certain height above ground and in an upright position).

Obviously, if we have shots fired from positions that are relatively close together and/or the cartridge case locations are not representative of their actual points of coming to rest, we cannot do anything beyond making a very general statement regarding their significance. Such a statement might be "The cartridge cases were all generally located on the east side of the room indicating a shooter toward the west side of the room."

When shots are fired from weapons where significant changes in position are involved, such as from moving vehicles, the situation becomes more complex. The ejected cartridge case location will be dependent on the velocity of the cartridge cases to a large degree. For example, if shots are fired from a weapon that ejects forward and the shots are fired in the direction of travel, the ejected cartridge case velocity will be the sum of the forward velocities of the vehicle and the cartridge case itself. In other words, if the vehicle is traveling forward at 55 mph and the cartridge cases are ejected at 10 mph, the net forward velocity is 65 mph. This means, as one would expect, that the cartridge cases will wind up much farther downrange than the results of static testing would predict. This scenario is illustrated in Figure 8.5. Additional considerations would include appreciable winds and cartridge

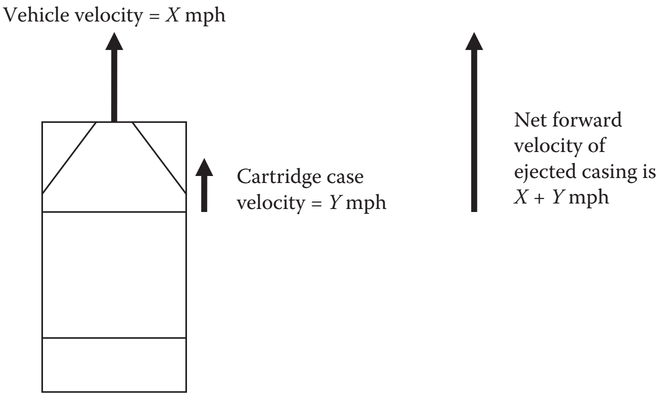

Vehicle velocity = X mph
Cartridge case velocity = Y mph
Net forward velocity of ejected casing is $X + Y$ mph

Figure 8.5 Net ejected cartridge case velocity.

case shape (e.g., a bottleneck cartridge case would have less tendency to roll as far as a standard cylindrical cartridge case).

Admittedly, the previous example is somewhat of an oversimplification for purposes of explaining the concepts involved. A perhaps more realistic scenario would involve a weapon being fired from a moving vehicle with the weapon being fired toward the side with a rearward and to the right ejection pattern as the vehicle moves forward. This type problem requires vector analysis to solve. As before, information as to how the weapon was positioned and the directionality of the shots is essential. If the forward vehicle velocity is known or can be estimated, the only remaining issue is the rearward velocity component of the ejected cartridge cases. It may be possible, in some instances, to determine cartridge case ejection velocity with a chronograph. The trick is getting the ejected cartridge cases to go through the chronograph screens. Admittedly, this is a bit of a stretch from a practical standpoint. But if we are able to estimate the cartridge case ejection velocity, the approximate point at which the shots were fired can then be determined. The rearward velocity component is solved using trigonometry as shown in Figure 8.6.

In any reconstruction involving cartridge case locations, substrate conditions are an important consideration. There is clearly a big difference in the relevance of fired cartridge case locations to shooter position with changes in substrate type/texture and grade or

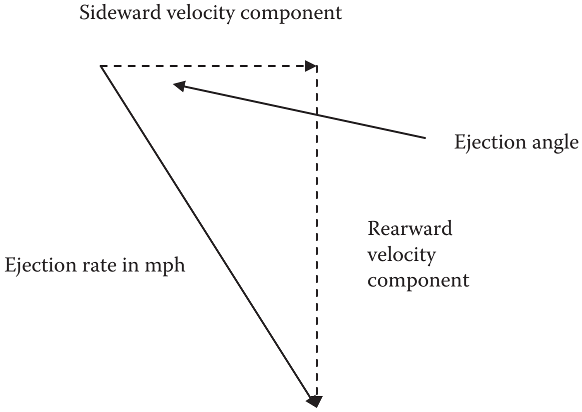

Sideward velocity component
Ejection angle
Rearward velocity component
Ejection rate in mph

Figure 8.6 Rearward velocity component.

incline. Thus, what the end result is for cartridge cases ejected onto flat, grassy ground as compared to a steep incline of concrete likely shows significant variation. The key aspect of using cartridge case location, under any scenario, is to carry out testing under similar circumstances. In the previous discussion of cartridge case ejection velocity components, the theoretical information that can be obtained from such calculations pales in comparison to the results of tests designed to simulate the circumstances of the shooting as nearly as possible. This is sometimes impossible to do because of the conditions that would have to be achieved. In those cases, testing can still provide some useful information that can be of help in reconstructing the shooting.

How tightly a semiautomatic handgun is gripped can, in some instances, affect the recoil action of the weapon. An extremely light grip can, for example, cause the weapon to fail to eject. However, being able to ascertain how tightly a weapon might have been held during a shooting is obviously beyond the realm of reason in nearly every shooting reconstruction. The net result is that a "standard" grip is applied when carrying out test firing.

The presence of various obstacles within the shooting scene (i.e., chairs, tables, vehicles, other individuals) changes everything with regard to ejected cartridge case location and predicting shooter position. Likewise, the movement of various people within the scene can alter cartridge case locations and must be considered. This is especially important as the number of cartridge cases gets smaller. Thus, if there is only one cartridge case present in a shooting scene, extreme caution must be exercised in applying a great deal of significance to the cartridge case location. On the other hand, even what appears to be a pattern may have another explanation.

In one case involving an officer, seven cartridge cases from the officer's weapon were found on the street between the officer's car and the curb. The car was approximately 3 feet from the curb. The officer's recollection was that all the shots were fired from the area between the car and the curb. The officer did not recall moving during the shooting. The wounds to the defendant were such that the officer had to change positions during the shooting. The cartridge cases seemed to support the officer's recollection of events.

Test firing and cartridge case location analysis showed that what actually must have happened is that four shots were fired from the officer's original position and the remaining three shots were fired from the opposite side of the vehicle. The fired cartridge cases from the second position undoubtedly landed on the rooftop of the vehicle and then bounced off onto the street in the same area as the cartridge cases from the first position.

Methodology

The determination of cartridge case ejection patterns requires the following:

- The incident weapon
- Ammunition like that used (preferably from the same lot) in adequate quantity (at least a full magazine)
- Similar terrain to that at the shooting
- A tripod
- Two 100 feet steel tapes
- Plastic markers
- Information as to how the gun was positioned during the shooting

The tripod is used to establish a known point to fire from. In officer-involved shootings, the officer is usually able to provide information as to his/her position when the shots were fired. Using this information, a tripod is set up to the appropriate height in the test area. The test area should conform to the terrain at the shooting scene. Otherwise, if general patterning only is being determined, a sandpit provides a surface for which little or no cartridge case bounce upon impact will be encountered.

The weapon is loaded with a full magazine and positioned using the tripod as a support that allows reproducibility of the height the weapon is fired from. A steel tape provides a convenient baseline that may be laid out on the ground. The baseline is set up so that it is in line with the plane of the breech face of the weapon. A second steel tape is laid out perpendicular to the first, crossing at the 50-foot mark of each. This provides an easy way to reference *X*, *Y* position coordinates for each fired cartridge case. As each shot is fired, a marker is placed next to the final resting place of the cartridge case. The setup is illustrated in Figure 8.7.

As an example, suppose this setup was used to test fire a .25 automatic pistol and that the following data were collected for the 10 rounds fired.

Shot #	*X* Coordinate (inches)	*Y* Coordinate (inches)
1	24	22
2	20	21
3	18	23
4	20	22
5	19	24
6	20	18
7	17	20
8	21	19
9	16	17
10	20	24

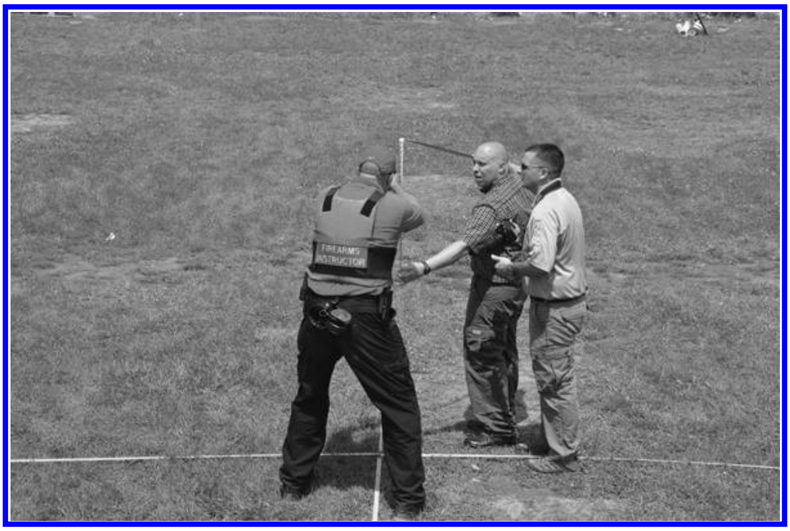


Figure 8.7 Ejection pattern setup.

The cartridge case ejection pattern is expressed in terms of the average angle to the rear (for this example) at whatever the average distance is found to be. This can be represented by a right triangle the dimensions of which are shown in Figure 8.8.

The values for average X and average Y are determined by adding the respective columns in the preceding table and dividing by 10 (the total number of entries). Doing this, one obtains the following:

$$\text{Average } X = 217/10 = 21.7 \text{ inches}$$

$$\text{Average } Y = 227/10 = 22.7 \text{ inches}$$

We can then solve for the average ejection distance using the Pythagorean theorem:

$$C^2 = A^2 + B^2,$$

where A is the average value of X, B is the average value of Y, and C is the average ejection distance.

Substituting, we get

$$C^2 = (21.7)^2 + (22.7)^2$$

$$C^2 = 470.89 + 515.29 = 986.18$$

$$C = \text{square root of } 986.18 = 31.4 \text{ inches}$$

This means that the average ejection distance is 31.4 inches. The average ejection angle can be found by taking the values for the sides of the right triangle and using one of the trigonometric functions. A convenient function to use in this example is the sine function. We recall that the sine (sin) of any angle is the ratio of the length of the side opposite the angle divided by the length of the hypotenuse (the side opposite the 90° angle). In this case, the length of the side opposite is 22.7 inches and the length of the hypotenuse is 31.4 inches as calculated above. This gives

$$\text{Sin of the average ejection angle} = 22.7/31.4 = 0.7229$$

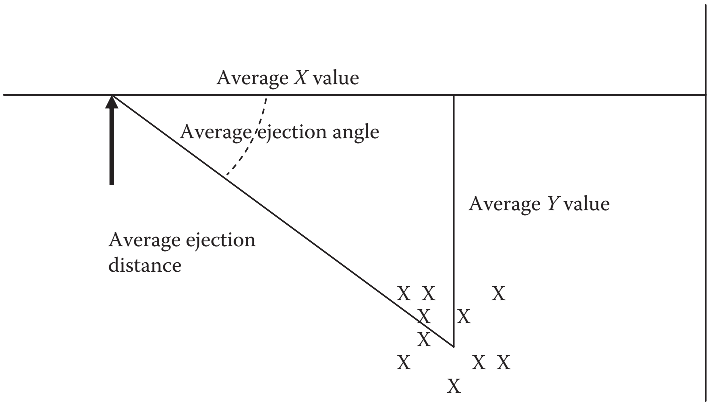


Figure 8.8 Ejection pattern determination.

The average ejection angle is the inverse sin of 0.7229 or 46.3°. The average ejection pattern then is rearward and to the right at an average angle of 46° from the plane of the breech face at an average distance of approximately 31 inches.

Interpretation of Results

How do we apply this to the cartridge case locations at a shooting scene? The answer is that we compare the average ejection characteristics to the actual locations at the scene to determine if they are reasonably close or not. If not, we must come up with an explanation as to why. Possible explanations would include relocation of cartridge cases and shooter movement.

In summary, in order to be able to use cartridge case locations to help reconstruct shootings, we must first know that their positions can be relied on. Knowing that, we must have some idea of directionality for the shots involved. We must then carry out test firing that duplicates every aspect involved as closely as possible. Finally, we must be careful as to how much significance we give to our findings because of the many unknowns that may be involved.

We have limited this discussion to semiautomatic weapons. It could just as easily be applied to fully automatic weapons. Slide action weapons, bolt action, lever action, and other manually operated actions add the problem of not knowing just how vigorously the action might have been operated. These, too, can be tested by using a "soft, medium, and hard" approach, if desired, or by just going with a "moderate" amount of force when working the action. Of course, positioning is of major concern as the action is worked, because that can directly affect where the fired cartridge cases will land.

Exercises

1. A weapon is fired from the bed of a pickup truck toward the rear as the pickup is traveling down a dirt road at approximately 25 mph. The weapon is an SKS 7.62 × 39 rifle that ejects forward. Under these conditions, will the ejected cartridge cases tend to end up closer to the point of firing or farther away?

   Answer: It would require knowing how fast the ejected cartridge cases exit the weapon to know for sure. The net velocity would be the difference between the forward velocity of the pickup (25 mph) and the rearward velocity of the cartridge cases exiting the weapon as it is fired to the rear.
2. At a shooting scene, two separate groups of fired cartridge cases are found on the ground. It is established that they were all fired from the same weapon. What would be required in order to help reconstruct the shooting?

   Answer: Some idea of the bullet trajectories and the results of ejection pattern testing of the weapon.
3. A shooting takes place in which several fired cartridge cases wind up on the floor inside a bar. There are numerous tables and chairs present. What sort of information can the fired cartridge case locations provide?

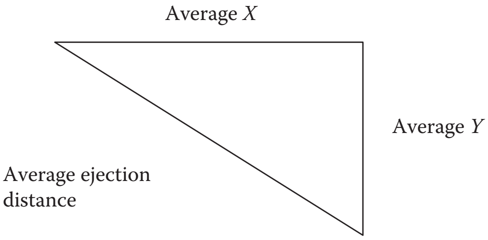
   Answer: Little or none because the obstacles (chairs and tables) present would have resulted in the ejected cartridge cases striking them and bouncing off in unpredictable directions.

4. Cartridge case ejection testing shows cartridge cases will be ejected from a particular weapon approximately 3 feet to the right rear of the shooter. Six cartridge cases are found within approximately 12 inches of each other. What possible position(s) could the shooter have been in?

   Answer: Without knowing anything about the bullet trajectories, the shots could have been fired anywhere within approximately 3 feet of the center of mass of the group of fired cartridge cases.
5. Use the cartridge case position coordinates to determine the average ejection distance and the average ejection angle from the plane of the breech face.

Shot 1	$X = 37$ inches	$Y = 30$ inches
Shot 2	$X = 30$ inches	$Y = 34$ inches
Shot 3	$X = 32$ inches	$Y = 20$ inches
Shot 4	$X = 29$ inches	$Y = 33$ inches
Shot 5	$X = 42$ inches	$Y = 29$ inches
Shot 6	$X = 36$ inches	$Y = 34$ inches

Answer: First determine the average *X* value by adding the *X* coordinates and dividing by 6. Then do the same for the *Y* coordinates. This yields 34.3 inches for *X* and 30.0 inches for *Y*. Next use the Pythagorean theorem to solve for the average ejection distance (the hypotenuse of the imaginary right triangle formed from the shooter's position to the center of mass of the cartridge cases).



$$(\text{Average ejection distance})^2 = (\text{Average } X)^2 + (\text{Average } Y)^2 = (34.3)^2 + (30.0)^2$$

$$(\text{Average ejection distance})^2 = 1176.49 + 900.00 = 2076.49$$

$$\text{Average ejection distance} = \text{square root of } 2076.49 = 45.46 \text{ inches.}$$

The average ejection angle is found by using the sine function and the values for average *Y* and average ejection distance:

$$\text{Sin Average ejection angle} = \text{Average } Y \text{ distance/Average ejection distance}$$

$$\text{Sin Average ejection angle} = 30/45.46 = 0.6599$$

$$\text{Average ejection angle} = \text{arc sin of } 0.6599 = 41°$$

Suggested Readings

Fisher, Barry A.J., *Techniques of Crime Scene Investigation*, 4th ed., Elsevier, New York, 1987.

Garrison, D.H., *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crimes Involving Gunfire*, Universal Publishers, Boca Raton, FL, 2003.

Garrison, D.H., Reconstructing Drive-by Shootings from Ejected Cartridge Case Location, *AFTE Journal*, Vol. 25, No. 1, Jan. 1993, pp. 15–20.

Haag, L.C., Cartridge Case Ejection Patterns, *AFTE Journal* 30:2 (Spring 1998).

Lee, Henry C., *Henry Lee's Crime Scene Handbook*, Academic Press, New York, 2001.

Shotgun Pattern Testing and Evidence Evaluation

9

Smooth bore weapons were the very first type of firearms ever produced and they persist to this day, albeit in highly refined forms. Shotguns are widely used in sport shooting (trap and skeet) as well as hunting. Shotguns come in a wide variety of configurations and designs, the most common of which are single barrel and double barrel (over/under and side by side barrel arrangements). The subject of this chapter is not shotgun operation and design, per se, but the end result of the discharge of shot shells—that is, the shot pattern and its significance in shooting reconstructions involving shotguns. Some examples of shotguns frequently encountered appear in Figures 9.1 through 9.3.

The pellets fired in shotguns are of two broad categories based on their intended targets: buckshot and birdshot. As previously discussed, buckshot pellets are designed for taking deer and other medium to large game animals. Birdshot on the other hand, is designed for use on game birds ranging from quail to geese and turkey. Law enforcement agencies that issue shotguns to their officers typically use 00 buckshot loads. The most commonly used 00 buckshot load in law enforcement consists of nine pellets; 00 buckshot loads with 12 pellets or 15 pellets are also used, although not as frequently by law enforcement. Slugs are also issued by many departments and typically have rifling cast into them for spin stabilization even with smooth bore barrels.

Typical shotgun shell configurations are shown in Figures 9.4 through 9.7.

Shotgun shell construction characteristics (for U.S.-manufactured models) typically consist of plastic tubes with brass bases (low base for standard loads and high base for magnum loads). All plastic shells as well as paper shells with brass bases are also available.

Low base and high base shot shells are shown in Figures 9.8 and 9.9, respectively.

The Drug Enforcement Administration (DEA) has done quite a bit of work to refine the patterns produced by shotguns their agents are issued over the years. As part of their research several years ago, they found that the use of eight 00 pellets improves the patterns obtained. This was demonstrated to the author at the DEA firing range in Quantico, Virginia, several years ago. It was clearly shown that by having only eight rather than nine pellets, fewer “fliers” (pellets that strike well outside the area where the majority of the pellets strike) are produced. This is likely attributable to the resultant “even” stack (2 × 2 × 2 × 2 rather than 2 × 2 × 2 × 3) and less pellet to pellet impact upon discharge and the subsequent reduction in pellet distortion. Distorted pellets, being less aerodynamic, tend to travel erratically.

Typical 8 pellet tactical shot shell components (Figure 9.10) have an even stack versus the odd stack for a 9 pellet load (Figure 9.11).

Working with Federal Ammunition Company, the Federal Tactical 00 Buckshot round was developed. A further improvement was the inclusion of a special thick-walled shot cup that produced much tighter groups at extended distances, thereby enhancing the tactical effectiveness of shotguns for law enforcement use.

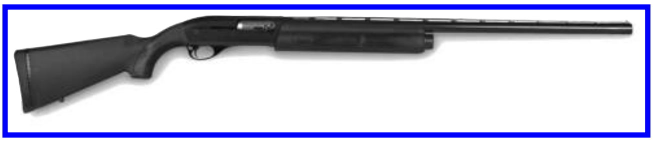


Figure 9.1 Remington semiautomatic shotgun.

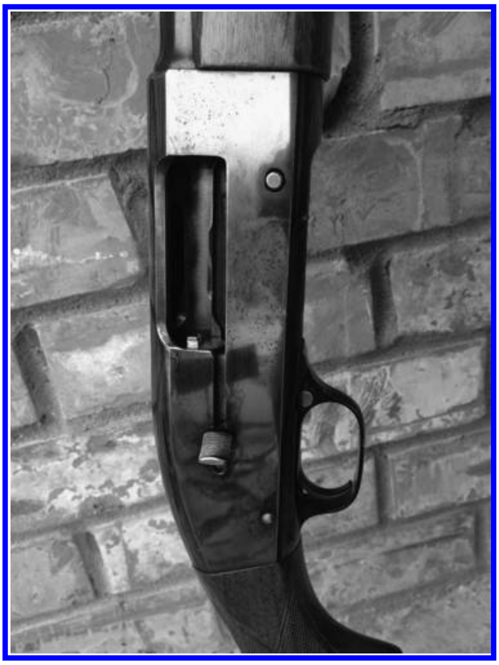


Figure 9.2 Winchester semiautomatic shotgun.

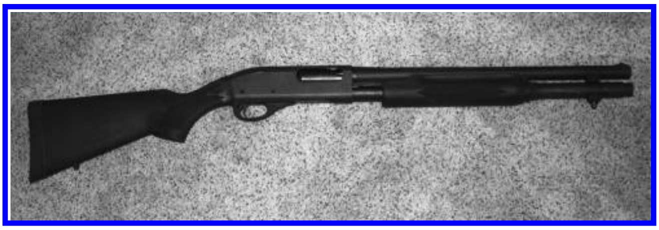


Figure 9.3 Remington 870 pump shotgun—standard police issue shotgun.

Typical tactical shot cups are much thicker than standard shot cups as shown in Figures 9.12 through 9.14.

When shot pellets exit the shot shell upon discharge, they are close together in a column. It is during the course of their travel down the barrel that interpellet collisions occur (particularly buckshot unless held together within a shot cup). Upon exiting the muzzle, the pellets begin to move apart. They continue to move apart with distance, assuming a conical distribution. Ultimately, of course, the effects of gravity and air friction bring wads, shot cups, and, ultimately, the pellets to ground.

Shot wrappers and shot cup upper leaves/bodies prevent contact between the shot pellets and the interior surfaces of shotgun barrels (particularly important when firing steel shot owing to likely excessive wear from steel on steel). Shot wads and shot cup bases

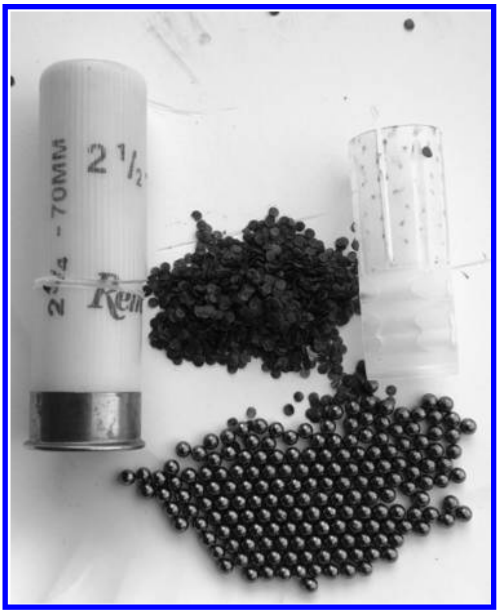


Figure 9.4 Disassembled 20-gauge Remington birdshot round.

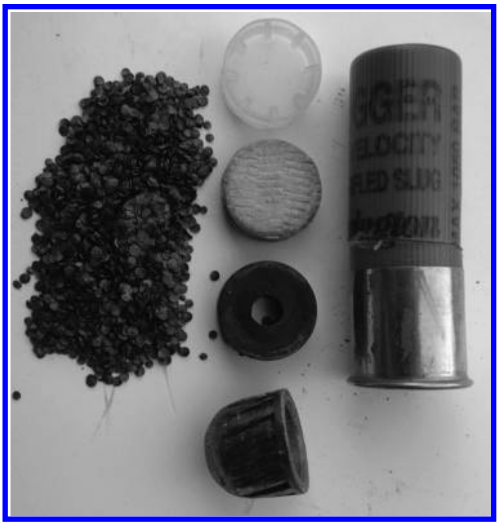


Figure 9.5 Disassembled Remington 12-gauge slug round.

separate the powder charge from the pellets. At close range, these devices often penetrate the wound and are recovered at autopsy. They travel with sufficient velocity to penetrate human tissue at close range in and of themselves. An officer in one of the author's shooting reconstruction classes described being hit by a shot cup at about 20 feet and having the shot cup penetrate his side. It is not uncommon for the impact of shot cups to produce dents in vehicle body panels upon impact at close range. This is particularly likely with heavy-walled tactical shot cups. However, even the standard wads and shot cups (Figure 9.15) can produce damage/injury, particularly at close range.

In numerous test firings with 12-gauge 00 buckshot at shooting ranges, the author has observed that shot cups and wads travel pretty much in straight paths and can travel as

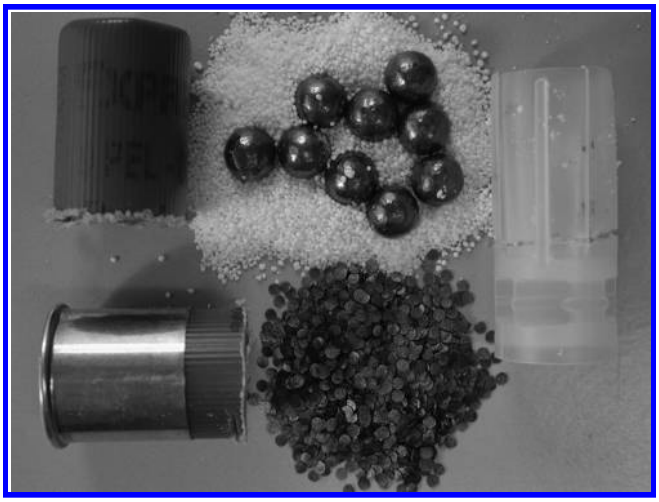


Figure 9.6 Disassembled Remington 12-gauge 9-pellet 00 buckshot.

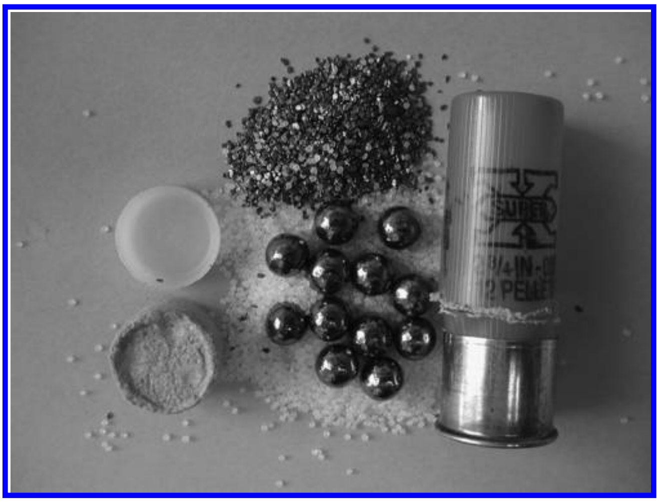


Figure 9.7 Disassembled Winchester 12-gauge 12-pellet 00 buckshot.

Figure 9.8 Federal Tactical 12-gauge 8-pellet 00 buckshot.

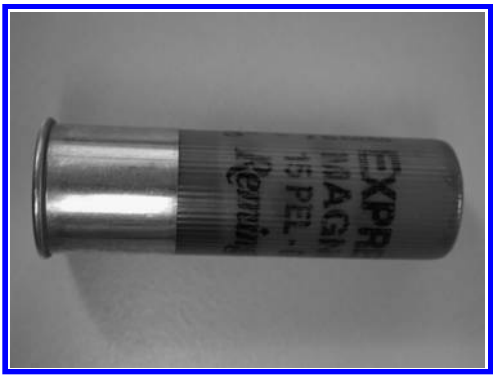


Figure 9.9 Remington Magnum 12-gauge 15-pellet 00 buckshot.

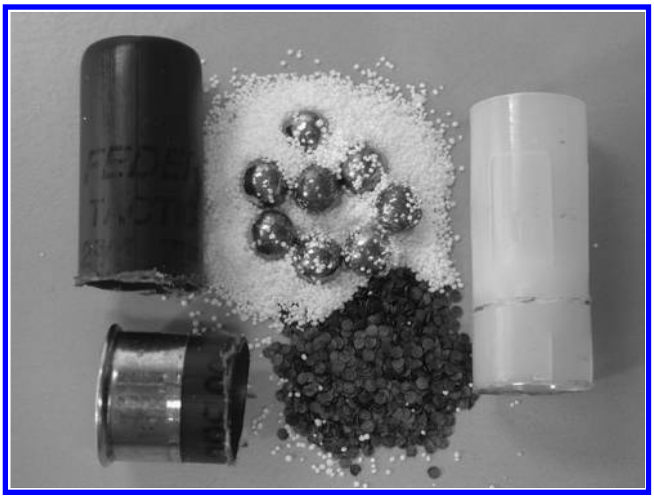


Figure 9.10 Disassembled Federal Tactical 12-gauge 8-pellet 00 buckshot round.

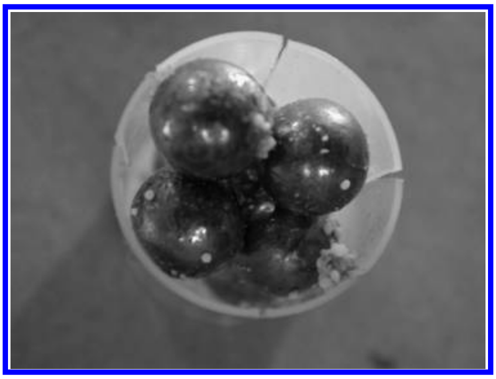


Figure 9.11 Standard 9-pellet stack.

much as 40 yards downrange. Locating shot cups and wads in the field can be a challenge, however. If located, they can provide information as to gauge and manufacture. A word of caution must be given with regard to 12-gauge versus 16-gauge shot cups and wads. There have been instances where 16-gauge shot cups/wads were used in 12-gauge shot shells by the manufacturer because of shortage of 12-gauge components. Thus, finding a 16-gauge

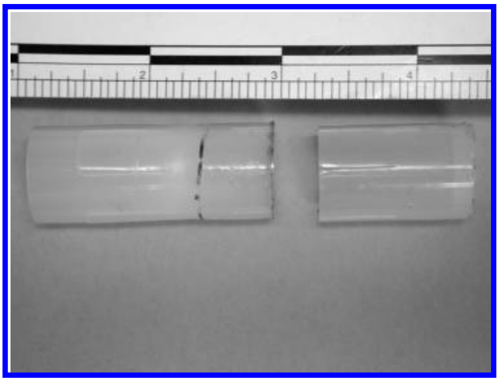


Figure 9.12 Federal Tactical FLITECONTROL (left) versus standard shot cup (side view).

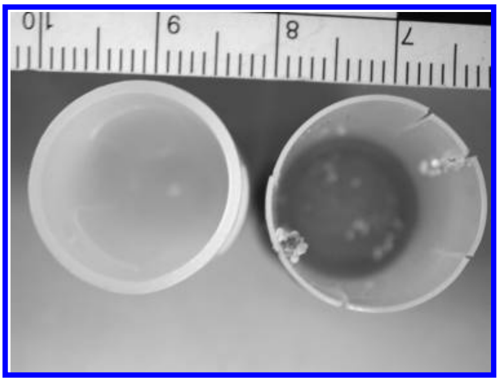


Figure 9.13 Federal Tactical FLITECONTROL (left) versus standard shot cup.

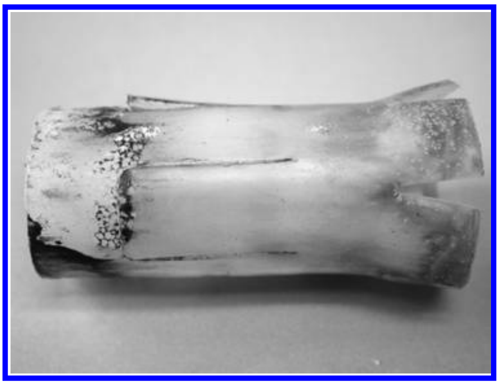


Figure 9.14 Federal Tactical FLITECONTROL shotcup—fired.

shot cup/wad at the scene is not an absolute indication of the use of a 16-gauge shotgun. The reverse situation, 12-gauge shot cup/wad in a 16-gauge shot shell, is not feasible.

When a tactical style shot cup is found at a scene, the presumption is that it originated from a police weapon. Federal Tactical eight-pellet 00 buckshot rounds are designated for law enforcement only, but we all are more than aware that the bad guys can get their hands on some from time to time. Fired shot cups can be identified as having come from buckshot

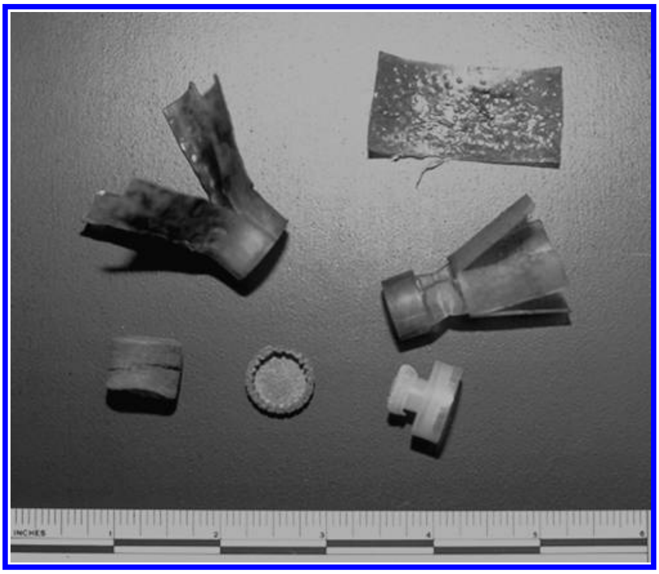


Figure 9.15 Shot cups, a wrapper, and wads.

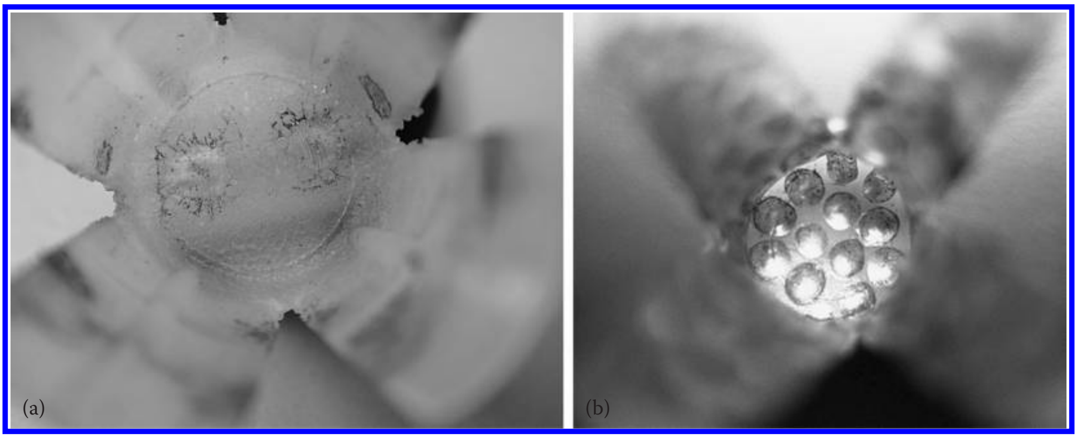


Figure 9.16 (a) Standard 9-pellet 00 buckshot shot cup—fired. (b) Birdshot impression in shot cup.

loads by the impressions found in the inside base surface as shown in Figure 9.16a and b. Birdshot is easily distinguished based on the impressions produced. Thus, even if no pellets are found, but a shot cup is, relative shot size may be determined. Preliminary studies by the author have revealed that closely related birdshot sizes (e.g., #7 1/2 and #8) are difficult to distinguish in some instances. Birdshot is contrasted with buckshot in Figure 9.16a and b.

Approximating Muzzle-to-Target Distance

When a more or less complete buckshot pellet pattern is present on a substrate, a rough rule of thumb may be used to approximate the muzzle-to-target distance. The rule is

> For each inch of buckshot pellet pattern spread, add approximately 1 yard of muzzle-to-target distance.

Note: This "rule of thumb" originally referred to standard (i.e., nontactical) nine-pellet 00 buckshot being fired in full choke barrels

In other words, if we have a somewhat circular pattern of nine-pellet 00 buckshot holes in a door, wall, or other object, we can measure the diameter of the pellet pattern and use the 1-inch-to-1-yard rule to approximate the shooter position. However, it cannot be emphasized enough that this is only a very rough approximation (even for standard nine-pellet 00 buckshot) that is only useful for the purpose of narrowing the field of search for additional evidence of shooter position (i.e., fired shot shells, footwear impressions, trace evidence) at the scene.

The reason that this rule of thumb is only a generalization is apparent when one considers all the variables that would be associated with the diameter of a shot pellet pattern for any size pellet (other than muzzle-to-target distance). These variables include:

- Gauge
- Choke
- Barrel length
- Pellet size

The term "gauge" is an old English designation for the bore diameter. It specifies the number of lead shot of that particular diameter to the pound. Accordingly, a 12-gauge shotgun barrel has a bore diameter such that 12 lead shot of that diameter would weigh 1 pound. Likewise, a 20-gauge shotgun has a bore diameter that equates to 20 lead shot to the pound. That means, of course, that the bore of a 20-gauge is significantly smaller than that of a 12-gauge. The difference in muzzle bore diameter changes the pattern obtained at a given distance.

Whereas many police issue shotguns have a barrel with no built-in constriction or "choke," many shotguns have chokes, which alter the pattern obtained at a given distance relative to a weapon without a choke ("cylinder bore"). Chokes are used to increase the effective distance of the pellets by keeping them together longer (i.e., decreasing the rate of spread over distance). Law enforcement issue shotguns are frequently Remington 870 pump action with no choke (cylinder bore). A firearm examiner can determine barrel choke either by using a choke gauge or by measuring the bore with a set of calipers.

Barrel length can affect pellet patterns as well. We would not expect exactly the same diameter pellet pattern for a 36-inch barrel versus a 26-inch barrel, for example. Likewise, a severely shortened barrel would exhibit a different pattern as compared to the unaltered version.

Pellet size has a significant effect on the pattern obtained. One obvious explanation is that the smaller the pellet size, the greater the effect air friction has on it. In the course of numerous range tests, the author has found that although nine-pellet 00 buckshot approximates the 1-inch-to-1-yard rule of thumb fairly well in some instances, in others it is not even close. Perhaps the most interesting pattern the author ever produced in a shooting range demonstration is illustrated in Figure 9.17 (unfortunately, no photograph was taken to memorialize it). The pattern left the author speechless and provided subject matter for later reflection.

Based on numerous test firings, if Remington eight-pellet Tactical 00 buckshot loads are used, a pattern of about 1 inch to 2–3 yards of muzzle-to-target distance (depending on barrel length and choke) can be produced. In other words, the Remington Tactical round

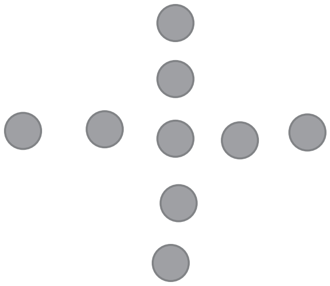


Figure 9.17 00 buckshot pattern.

allows an officer to fire from a greater distance than that required for a given pattern using standard nine-pellet 00 buckshot rounds. Birdshot typically varies significantly from the 1-inch-to-1-yard rule as well. The bottom line is that test patterns must be obtained in order to be able to make any reliable statements concerning distance required for a given round to produce a given pattern.

So far, the discussion has focused on straight-on shots (90° impact). What about shots fired at other angles? When a shotgun is fired at an angle significantly less than 90°, the pattern typically approximates an oval in shape. It is the short axis of the oval that is used to approximate muzzle-to-target distance based on the 1-inch-to-1-yard rule when nine-pellet 00 buckshot is involved.

Although shotguns, by definition, are smooth bore weapons, barrels are available with rifling for firing slugs. The presence of rifling drastically alters the pellet pattern for birdshot. Figures 9.18 and 9.19 show shots fired at the same distance (4 feet) using the same loads and same barrel lengths, but one has a rifled bore (a Hastings® barrel) and the other the standard smooth bore.

The conclusion that is drawn from all this is, once again, the real answer to approximating shooter position comes with carrying out test firing using the weapon and similar ammunition into material similar to the target material.

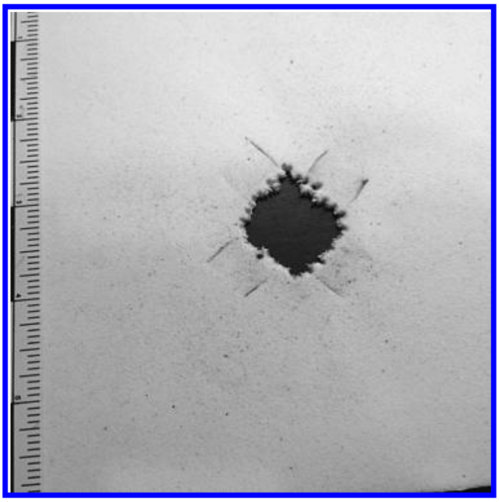


Figure 9.18 12-gauge #8 shot at 4 feet.

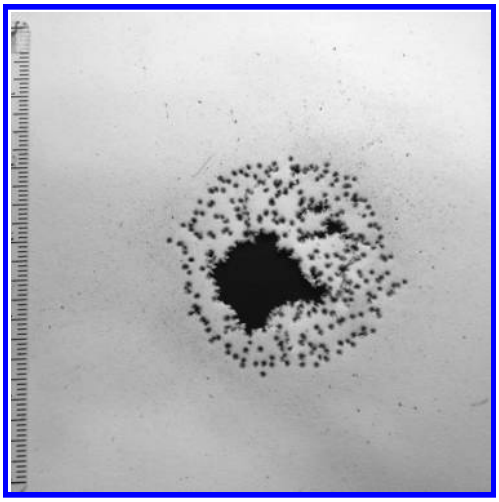


Figure 9.19 12-gauge #8 shot at 4 feet with rifled barrel.

Another general rule of thumb is that all shotguns tend to produce large, circular holes out to about 2 feet muzzle-to-target distance, large, circular holes with irregular margins between 1 and 3 feet, and large, circular holes with irregular margins and individual pellet holes starting at about 3 feet. This also must be verified through testing for each specific set of circumstances and is only useful for very general investigative purposes.

An additional consideration related to approximating shot distance on the basis of pellet pattern spread has to do with intermediary targets. When pellets first impact an intermediary target, the pattern "opens up." This can lead to an estimation of shot distance that is greater than the actual if the intermediary target effect is not taken into consideration. Testing must be carried out in order to assess what the actual effect on pattern size is for a given intermediary target.

Angle of Impact Estimation

The angle of impact for a shot pellet pattern may be determined from the axes of the overall pellet pattern. In many instances, an oval can usually be approximated that incorporates the pellet impacts. Sometimes there are "fliers" that can be ignored. Using the short axis and long axis and the sine relationship, the angle of impact can be calculated as previously discussed. If a very erratic pattern is produced, other methods can be used to compare patterns. These include drawing rectangles instead of an oval around the pattern.

When 00 buckshot or similar size shot has been used, the individual pellet strikes can be used. By taking three different pellet holes/marks, calculating the angles of impact for each and averaging, a check of the result from the overall pattern analysis can be made.

In summary, using the short axis and the 1-inch-to-1-yard rule of thumb, we approximate the muzzle-to-target distance when nine-pellet 00 buckshot is involved, and using the width/length ratio of the overall pattern (and/or individual pellets) for any type pellet we can determine the angle of impact. The combination, along with other physical evidence, allows the approximation of shooter position in many instances.

Test Firing

In carrying out shotgun pattern testing, as with any such testing, it is important to duplicate the circumstances of the shooting as nearly as possible. This means using the same shotgun and similar ammunition (same lot if possible) along with the same substrate unless general patterning only is desired. A minimum of two shots should be fired from each distance to establish reproducibility.

When only general pattern testing is desired or when gunshot residue deposition (soot and/or powder stippling) is the concern, there are several suitable media that can be used (see Hueske 2011). The author has used foam board (white poster board with a piece of Styrofoam in between) and Kraft paper (foam sheets) as a test media for many years. Additionally, clear plastic sheet and cotton twill cloth can be used depending on circumstances and residue of interest. The main problem encountered with foam board is when very close range shots (less than about 12 inches) are desired, the muzzle blast has a tendency to break apart the foam board. Kraft paper (foam sheet) is much more durable and has the best overall combination of soot residue retention and powder stippling representation. Clear plastic sheet is more sensitive for recording powder particle impacts consistent with producing stippling on human skin but fails to retain soot adequately. The investigator is encouraged to read the referenced article before selecting a substrate.

Figures 9.18 and 9.19 illustrate the use of Kraft paper for shot pellet patterning alone (there is no interest in soot residue or stippling).

SHOT PELLET PATTERN INDICATES HOMICIDE

An Idaho Sheriff's detective contacted the author several years ago and asked that a case be reviewed involving a shotgun death that had been ruled a suicide. The victim was found in his basement with a shotgun blast to the chest and a second shot to the left shoulder. Both shots were similar in that they consisted of large, circular holes with several individual pellet holes around the margins.

The shotgun was found lying on top of a large box and a bicycle fork was lying on top of it with one of the axle ends against the trigger. The obvious implication was that the bicycle fork had been used to fire the weapon. However, there were a number of issues regarding the scene. First of all, the shotgun would have had to have been held by the barrel when it was fired. Otherwise, the recoil would have caused it to fall off the box. An examination of the top of the bicycle fork and the gun barrel failed to reveal the presence of fingerprints.

More troubling, however, was the appearance of the two wounds. Both the wound to the chest and the wound to the left shoulder consisted of circular holes with individual pellet entries around the margins. This type of pattern typically shows up at about 4 feet muzzle-to-target distance. The fact that there were two wounds was not a major concern because multiple shots in suicides do occur from time to time. On the other hand, the locations of the wounds did not make a lot of sense considering the shotgun had to remain on top of the box during the two shots.

The answer as to homicide or suicide required test firing of the shotgun to establish the muzzle-to-target distance as closely as possible based on pellet pattern alone (there was no soot residue or stippling). Foam board was used as a test medium. The first test shot was fired at the distance of 4 feet as suggested by the wound appearance. Ultimately, it was determined that the approximate muzzle-to-target distance was 6 feet. Even with the bicycle fork being used to depress the trigger, there was no way the decedent could have shot himself with the muzzle of the shotgun 6 feet from his chest and shoulder. The case was then reopened as a homicide.

Graphical Analysis

Rather than trying to duplicate the pattern found at a crime scene, it is usually simpler to test fire at a minimum of three distances (two shots at each distance) and prepare a graph of the results. The graph can then be used to determine the muzzle-to-target distance for the particular pattern in question. An example of the graphical representation is shown in Figure 9.20. The light lines represent how the graph is used to determine a distance for a particular pellet pattern or to estimate pellet pattern for a given distance.

Shot Shell Buffer and Distance Estimation

Certain brands and types of shot shells contain a white granular material known as buffer (Figure 9.21). This material consists of a number of different possible morphologies and may consist of either polyethylene or polypropylene. The particular shape and formulation varies from manufacturer to manufacturer and within the product line of a particular manufacturer. As a result, some forensic significance can be attached when the material is recovered from a shooting victim's clothing or at the scene. Some of these different morphologies are clearly visible in Figure 9.22.

Shot shell buffer is advertised as reducing interpellet collisions and consequential pellet deformation. This is questionable, based on observations of numerous shots fired using

Range (yards):	2	3	4	5	6	7	8
Pattern (inches)	1.4	1.9	2.5	3.2	4.0	4.9	5.8
	1.6	2.4	2.9	4.2	4.8	6.3	6.5
	1.8	2.6	3.7	4.4	5.7	6.7	7.9

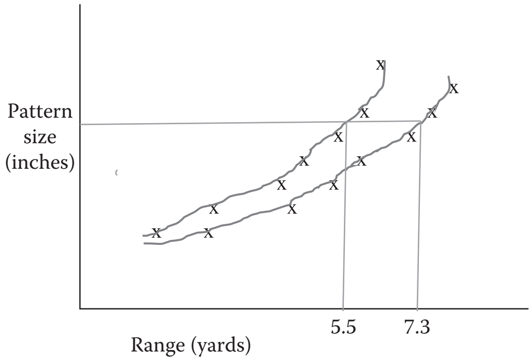


Figure 9.20 Graphical distance determination from shot pellet patterns.

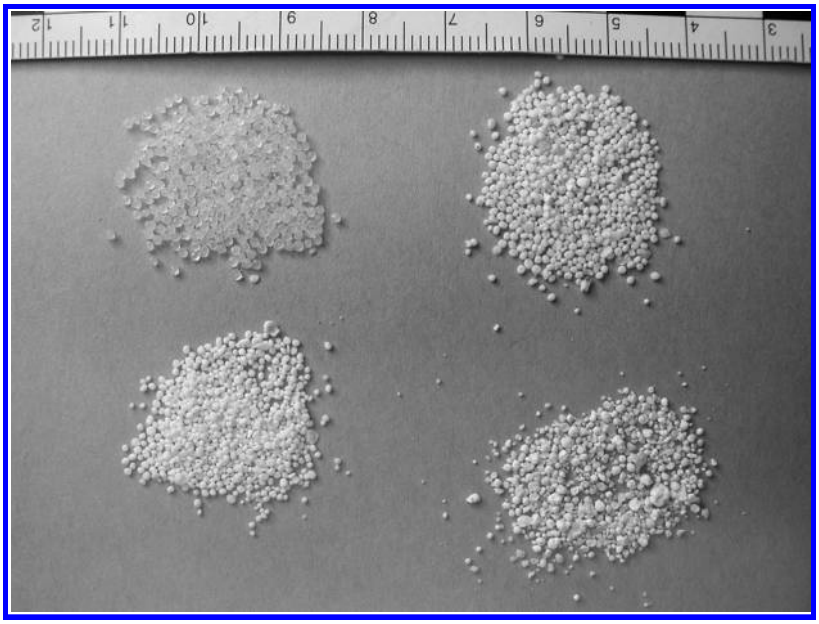


Figure 9.21 Buffer—Winchester 12 pellet, Remington 9 pellet, Remington 12 pellet, Federal Tactical 8 pellet (clockwise from upper left).

buffered 00 buckshot loads. The presence of buffer in slug loads obviously indicates another purpose: taking up space to prevent the slug from moving back into the shell case (the black plastic disk in Figure 9.5 accomplishes the same thing).

When a shot shell containing buffer is discharged, the buffer material exits the muzzle in a conical pattern similar to the gunpowder particles. Over time and distance, the buffer material falls to the ground because of the effects of air resistance and gravity. The horizontal distance that the buffer travels is primarily a function of the shape, mass, and initial

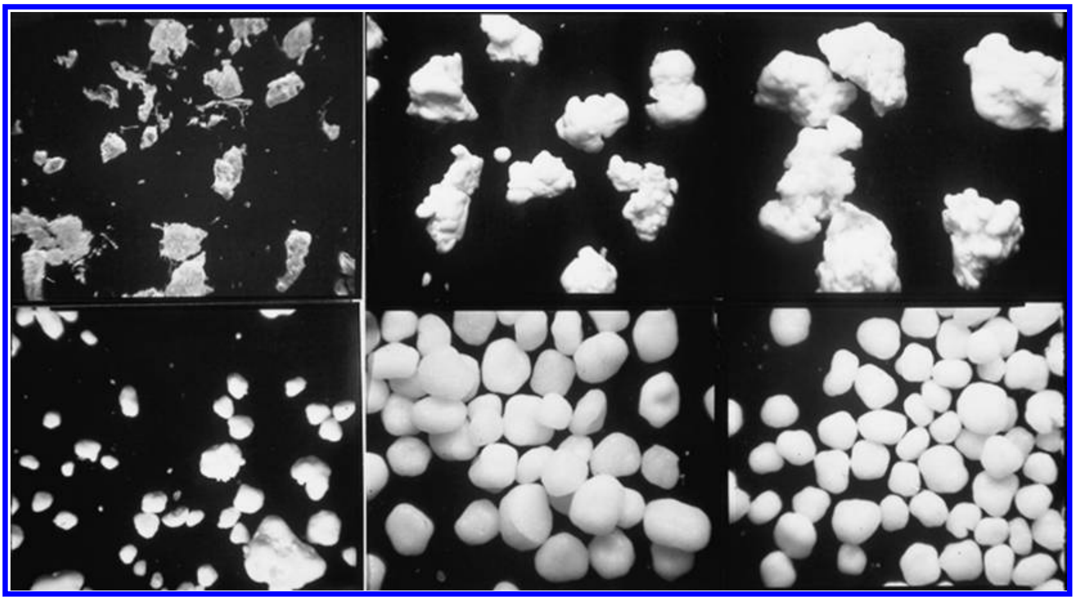


Figure 9.22 Different buffer morphologies.

velocity of the particles. In any event, there will be a finite distance, beyond which the buffer material would not be expected to travel. This information would have to be determined by testing under the circumstances of a particular case.

Buffered loads, such as Federal 00 buckshot, are frequently used by police agencies. Accordingly, the investigator should be on the lookout for buffer residue in a police shooting involving a shotgun. Finding the residue can help establish shooter position and direction of shots.

When buffer material is located and a suspect is apprehended with buffered loads in his possession, the determination of similar shape and composition for the buffer constitutes circumstantial evidence. The crime laboratory can easily identify the composition of the buffer using instrumental analysis.

Winchester markets a high-density polyethylene buffer (Figure 9.21, upper left) that has significantly better range of flight than standard buffers, thanks to its greater mass and aerodynamics (spherical). In research by the author, it was found that the density of the Winchester buffer was almost 50% greater. This also was determined to provide a greater propensity to penetrate clothing and to produce pseudostippling on human tissue.

Standard shot shell buffer has a horizontal range of approximately 6–8 yards according to research conducted by the author in 1983 (see Suggested Readings). Winchester high-density buffer was found to travel 13–14 yards horizontally in a study conducted by the author in 2010 (see references).

Reporting of Results

Shot shell buffer distributions should be reported as a range similar to the reporting of gunpowder particle test results. In the author's experience, however, a distinct pattern of buffer particles will not typically be achieved as occurs with gunpowder particles. The significance of finding buffer particles on clothing and other objects is more likely to be limited to being able to make a general statement regarding the distance. That statement would be something on the order of "This is indicative: Dillon, 3 of a shot being fired within the maximum distance at which buffer material would be expected to be deposited. Using the incident weapon and shot shells like that used in the shooting, this distance was determined to be between 10 and 11 yards."

In the event that an actual pattern of buffer particles is present, test firing could be carried out in the same manner as previously discussed in the section on graphical analysis of shot pellet patterns. The combination of pellet pattern testing and buffer pattern testing helps add validity to the conclusion reached as to the approximate muzzle-to-target distance.

SHOT SHELL BUFFER ON A VICTIM'S CLOTHING

A body was found in a grassy area near a housing project. The victim had several circular wounds to the right side of the head and neck. He was wearing a dark-colored flannel shirt. Several small granules of white material were observed to be adhering to the fibers of the shirt. Similar granules were found on the jeans. A plastic wad was also embedded in the shirt. At autopsy, several lead pellets consistent with 00 buckshot were recovered. Because there was no observable pellet pattern, no muzzle-to-target approximation could be made.

A suspect was apprehended a few days later. In his possession was a sawed-off 12-gauge shotgun and several rounds of Federal 00 buckshot. Further examination showed that the shot shells contained buffer material consisting of various sized spheres. Chemical analysis of the buffer confirmed its composition as polypropylene. Using the shotgun and similar ammunition, it was determined that individual shot pellets were first distinguishable at approximately 5 yards.

Microscopic examination of the buffer material from the victim's shirt and jeans showed it to be consistent with the buffer present in the shot shells in the suspect's possession. The plastic wad was found to be consistent with those in the suspect's shotgun shells. Test firing was then carried out to establish the maximum range at which the buffer material would be deposited on a test shirt like that of the victim. This was done by first establishing an approximate distance using dark-colored cotton twill. This was then followed by firing into cloth panels from the exemplar shirt and jeans. Ultimately, it was determined that the maximum distance that buffer material would be deposited on material like that from the victim's shirt and jeans was between 6 and 7 yards.

These results were used to establish an approximate muzzle-to-target range of 5–7 yards. The fact that the buffer material found on the victim's shirt and jeans was similar to that found in the suspect's shotgun shells provided circumstantial evidence of guilt. Based on these findings and other evidence of involvement, the suspect was charged and later convicted of the murder.

Evidence photographs are shown in Figures 9.23 through 9.25.

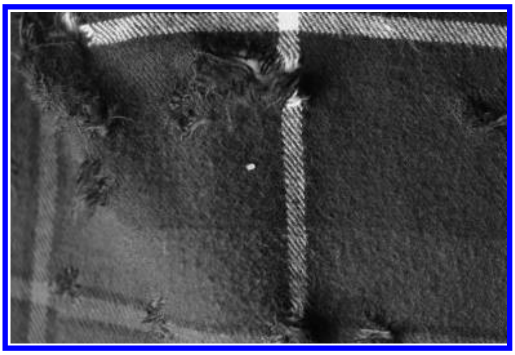


Figure 9.23 Buffer on flannel shirt.

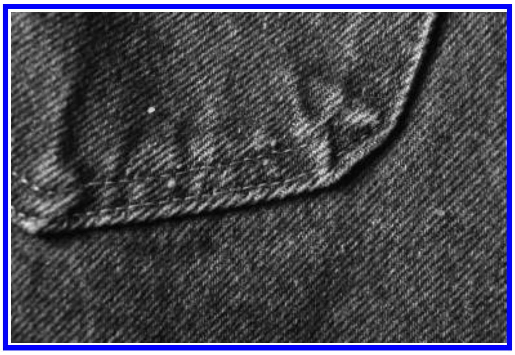


Figure 9.24 Buffer on seat of jeans.

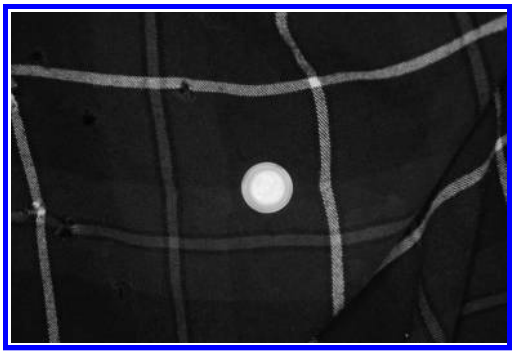


Figure 9.25 Plastic wad imbedded in flannel shirt.

Exercises

1. A shot pellet pattern in a door is observed to have somewhat of an oval pattern that measures 6 inches by 13 inches. For purposes of beginning a search of the scene, about how far away from the door should investigators look and in what direction?

   Answer: The 1-inch-to-1-yard rule suggests a distance of approximately 6 yards (short axis of the oval being 6 inches, 6 inches approximately equals 6 yards). The angle of impact equals the arc sin of the width (short axis) divided by the length (long axis).
2. Why does more than one shot need to be fired from each distance selected for shot pattern testing?

   Answer: Because pellet patterns will vary slightly at a given distance, more than one shot should be fired and an average taken.
3. If a measurable pattern is found on a victim's clothing in a shotgun shooting, how should testing be carried out?

   Answer: A minimum of two shots at each of three different ranges are fired and a graph of the results constructed. Using the graph, the approximate muzzle-to-target distance may be ascertained.
4. What forensic significance can be attached to shot shell buffer material?

   Answer: Chemical analysis can be used to relate evidence to suspect ammunition, and an estimate of distance for the shot can be facilitated by the presence of buffer material in the scene or on a victim.
5. What is the 1-inch-to-1-yard rule of thumb and how is it applied?

   Answer: For each inch of pellet spread for nine-pellet 00 buckshot, there is approximately 1 yard of muzzle-to-target distance. This is used to provide a starting point for searching for additional evidence of shooter position in a shotgun shooting. It generally shows great variation for birdshot. In any case, actual test firing must be carried out.
6. Examine Figure 9.26 and determine whether statements from witnesses that a shotgun and a handgun were being fired multiple time appears to have any validity. What, if anything, can you determine as to the number of shots and what should be done to determine the approximate shooter position in this incident?

   Answer: There are a total of 24 holes. The circular one to the upper left appears to be a straight-on shot (approximately 90° impact) caused by a projectile with a larger diameter compared with the others (i.e., a different caliber). Of the remaining 23 holes, four appear to be "doubles," making a total of 27. By measuring the

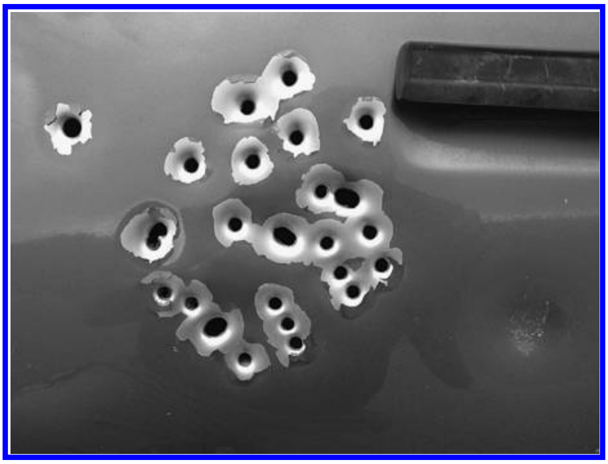


Figure 9.26 Door to a vehicle that was allegedly fired at with both a shotgun and a handgun.

hole diameters, we come up with 0.41 inch for the single hole to the upper left, suggestive of .40 caliber. For the remaining holes (single impacts) we get a diameter of approximately 0.35 inch, suggestive of 00 buckshot. Given the total number of holes represented (27), three shots with nine-pellet buckshot is suggested. The interior door panel needs to be removed and the entire interior of the vehicle searched for the responsible projectiles (bullet and shot pellets) in order to confirm our hypothesis. Test firing will be required to establish shot distances.

7. Officers responding to a New Year's Eve call of shots fired in a residential area arrived to find a man standing in his front yard in his underwear holding an AK-47 down at his side. One officer, armed with a Remington 870 shotgun with 00 buckshot, has his weapon pointed at the man as the second officer yells for the man to drop his gun (the AK-47). Instead of dropping the AK-47 the officers stated the man raised it in their direction upon which the officer fired his shotgun.

   The man was struck in the head by several pellets and killed. The AK-47 is shown in Figure 9.27. What, if anything, is suggested by the visible damage and what needs to be done forensically here?

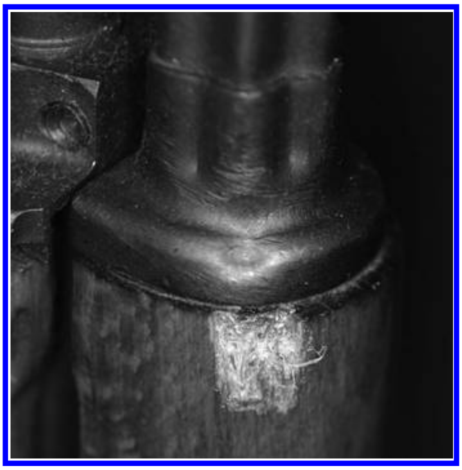


Figure 9.27 **(See color insert.)** Indentations to metal and wood of AK-47.

Answer: Both areas of damage need to be tested for lead and copper residues (the officer's rounds had copper-plated lead 00 buckshot). The indentation needs to be measured for consistency with 00 buckshot. Shot pattern testing needs to be done.

8. Officers examining the scene of a shotgun shooting into a mobile home from the street locate a green plastic disk with a number on it. A suspect is later apprehended and a shotgun shell in his possession is taken to the firearms unit where it is disassembled and a green plastic wad is recovered. The two plastic disks (wads) are noted to have different numbers (Figure 9.28). What, if any, significance is there to this?

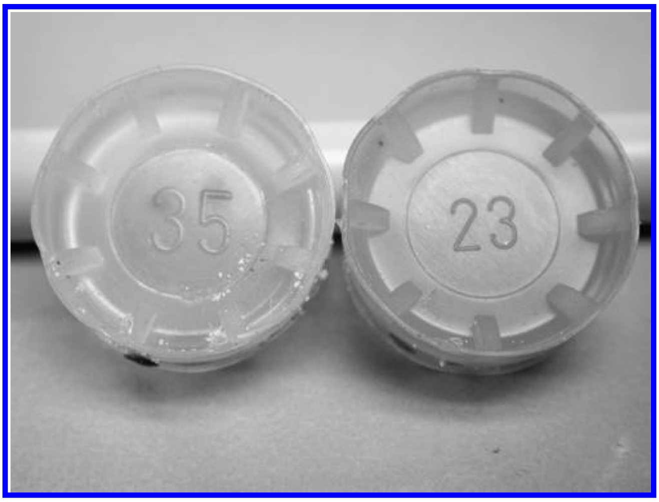


Figure 9.28 Plastic wads.

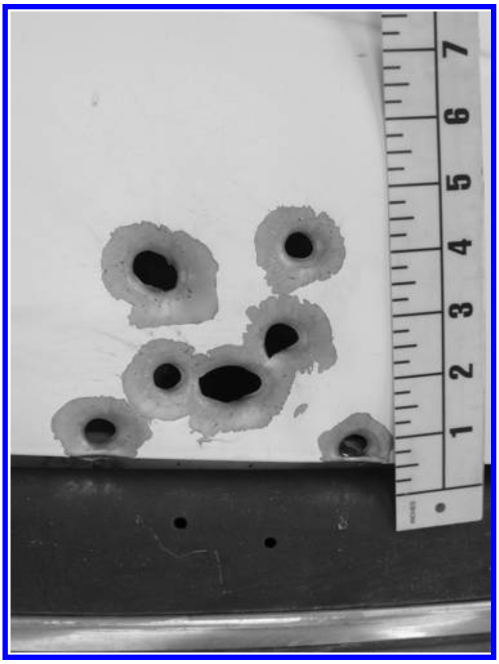


Figure 9.29 Apparent holes in metal and plastic.

Answer: The numbers are merely mold numbers and multiple numbers can be found within the same box of shotgun shells from time to time. In other words, having the same or different numbers is of no real significance. Similar numbers are sometimes also found on the base of shot cups and are equally of no real value.

9. A police patrol vehicle is struck with a shotgun blast. Examine the photograph (Figure 9.29) and give as much information as you can based on "face value."

   Answer: This appears to be a nine-pellet 00 buckshot round (with two double hits). Based on the rule of thumb, the distance of the shot appears to be from approximately 4–5 yards. Of particular interest are the small holes in the rubber trim piece below. They are consistent with hollow point bullets and not shotgun pellets. The trim piece must be removed, along with the interior door panel, so that a more accurate evaluation may be made. Shotgun pellet pattern testing will be required.

10. Figure 9.30 shows the victim of a shotgun blast from a few yards with most of the pellets missing, but a large number of reddish abrasions (stippling) was produced

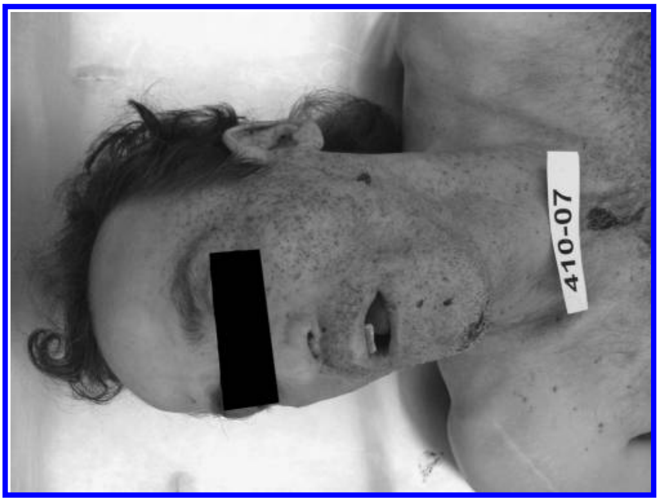


Figure 9.30 Apparent stippling on face.

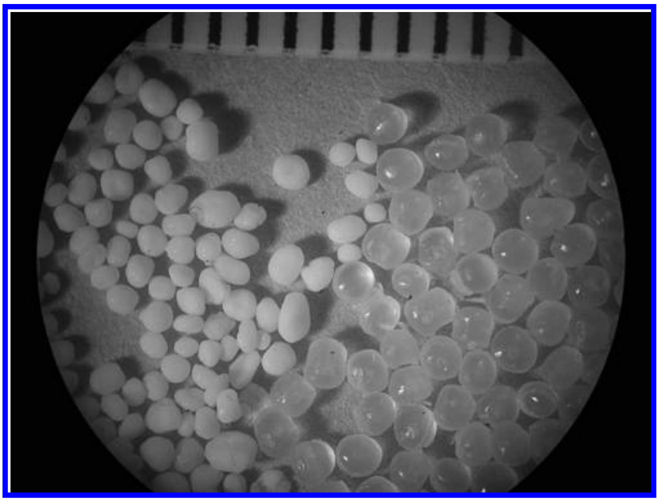


Figure 9.31 Winchester hi-density (right) compared to standard buffer.

on the left side of the face and neck. The assailant fired a Winchester 00 buckshot round at the victim who was killed in spite of only a few pellets actually hitting him (Figure 9.31). What can be concluded concerning the apparent stippling?

Answer: This is pseudostippling produced by the high-density buffer (Figure 9.30) striking and abrading the skin.

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Examination/Testing of Weapons and Ammunition Components

10

Shooting reconstruction typically involves examination and testing of weapons/ammunition components. A significant part of the examinations to be conducted focuses on the recognition and documentation of any trace evidence present. Weapons testing includes function testing, accuracy determination, and rate of fire determination in addition to ejection pattern testing as previously discussed.

Trace Evidence Examination

A wide variety of trace evidence may be present on firearms and ammunition components as a result of their use in shootings. This may include one or more of the following:

- Botanicals
- Hairs/fibers
- Glass particles
- Blood/tissue
- Fingerprints/DNA
- Gunshot residue
- Building materials (e.g., gypsum, wood, plastic, concrete)

Botanicals (plant materials) can adhere to firearms and fired bullets and cartridge cases as a result of contact at a scene. Botanicals may also adhere to individuals' clothing, footwear, and vehicles providing a means of "putting them at the scene."

A suspect was apprehended in a suspected "hit" in which a man was gunned down in his carport late one night upon returning home from an evening of drinking with some associates. The deceased's shirt was observed to have numerous small particles of green leafy material of unknown origin. Upon examination of the 9-mm handgun confiscated from the suspect at the time of his arrest, it was noted that some similar appearing particles were present on the muzzle end of the gun. Laboratory examination revealed that bits of marijuana were present on both the shirt and the gun. Upon questioning of the suspect, he stated that he had pressed a brick of marijuana over the muzzle of the gun in an effort to reduce the sound of discharge. Upon discharge, bits of marijuana had been blown everywhere. When asked where he came up with this idea, the suspect said he had come up with it on his own because the decedent was a drug dealer and had bricks of marijuana stashed in the carport that the shooter knew about.

Hairs and fibers are examples of transitory evidence that can easily be lost in the recovery, packaging, and transport of firearms and ammunition components. For this reason, it is extremely important that this evidence be visually inspected at the shooting scene and appropriate steps be taken to preserve it. When this is not done, the evidence may wind up in the bottom of the evidence bag and the examiner who receives the firearm or ammunition component may never realize it.

The nose cavities of hollow point bullets are particularly likely to retain trace evidence of all types. In some instances, the debris is present in layers that give a history of the bullets' progression through various substrates. Questions about shot order can sometimes be answered by the presence of this material. For example, if two shots have been fired through a vehicle side window and the glass collapsed after the first shot, the presence of glass particles in the nose of one bullet and not the other provides the answer as to which was first. A hollow point bullet with imbedded trace evidence is shown in Figure 10.1.

Bullets found at the scene can provide information about suspects. In one case the author was involved with, a burglar was shot at by a homeowner and the bullet passed through his clothing and was found on the floor by investigators. The burglar fled the scene. A suspect was later arrested and was observed to have two holes in his pant leg. Upon examination of the bullet, it was noted that fibers were imbedded in the nose (Figure 10.2). Laboratory analysis showed the fibers from the bullet to be consistent with fibers from the suspect's pants. This helped convict the suspect of breaking and entering.

When blood/tissue is present on firearms and ammunition components, DNA analysis can identify the source. On bullets this can be used to identify suspects who were shot but

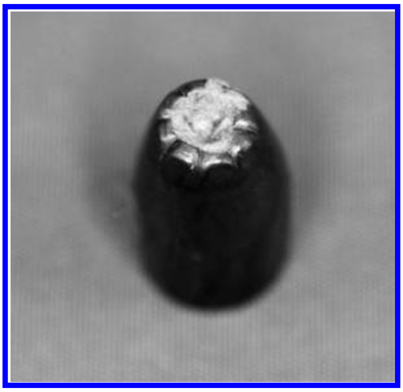

Figure 10.1 9-mm hollow point bullet with trace evidence imbedded.

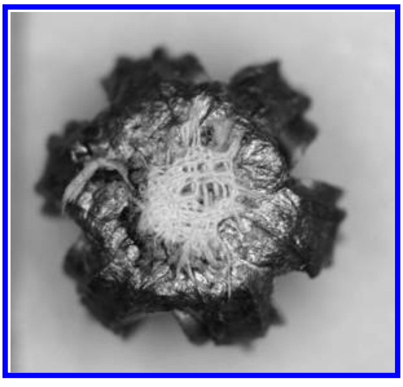

Figure 10.2 Fibers embedded in bullet nose.

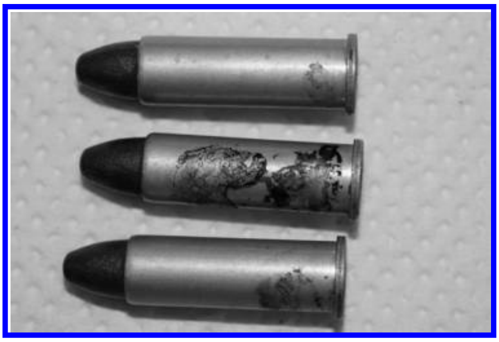

Figure 10.3 Blood on cartridges.

fled the scene. It can also be used to determine which bullet was responsible for passing through an individual. On weapons, blood/tissue can provide information as to shot distance, as is discussed in Chapter 11. DNA technology has advanced to the point that the mere handling of weapons and ammunition can provide sufficient DNA for identification purposes. Swabs of weapons (triggers, stocks, grips, etc.) are taken and used for this analysis. Figure 10.3 illustrates blood on cartridges.

Fingerprints are, contrary to what is frequently shown in television shows and movies, elusive when it comes to firearms and ammunition components. It is the author's experience that identifiable fingerprints are found in less than 5% of the cases involving firearms that are examined for their presence (Figure 10.4).

The number of identifiable fingerprints recovered from ammunition components, particularly fired cartridge cases, is even smaller than that for weapons. This is attributable to the small, curved surfaces typically involved. Also, the heat resulting from discharge vaporizes the fingerprint residue left on most cartridge cases. A ploy sometimes attempted by defense attorneys is to use the fact that their clients' fingerprints were not found on a weapon or ammunition as an indication of innocence. A statement coined by a forensic examiner years ago pretty much says it all: "Absence of evidence is not evidence of absence." Figure 10.5 illustrates what can sometimes be found.

The surfaces of many firearms are simply not conducive to retaining fingerprints. Even if the surfaces are conducive to retaining fingerprints, the manner in which most weapons are handled precludes the deposition of identifiable prints. Specialized techniques, such

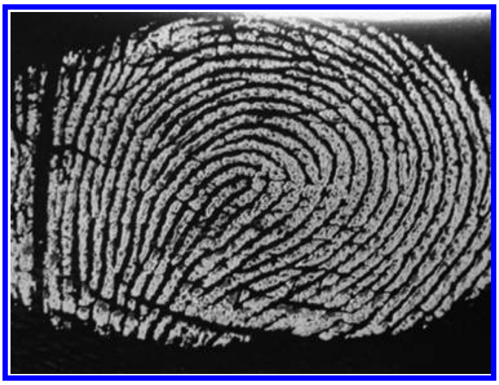

Figure 10.4 Superglued print on gun barrel.

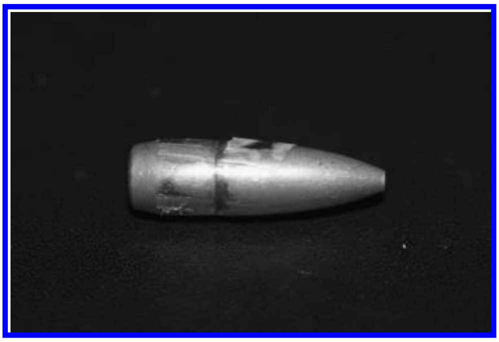

Figure 10.5 Trace evidence on bullet.

as infrared scanning, can sometimes work wonders with guns and ammunition components when more traditional enhancement techniques, such as super glue, are ineffective. Specialized methods can sometimes provide results as seen in Figure 10.6.

On the other hand, it should never be presumed that fingerprints are not present. The failure to examine and test these items is a crucial error. The watchword here should be "one test is worth a thousand excuses." From time to time, identifiable fingerprints do show up on weapons and even on fired cartridge cases (Figure 10.6). The only way to know for sure is to carry out testing.

A member of the Boston Police Department Crime Scene Unit, in attendance at one of the author's shooting reconstruction classes several years ago, advised the class that their department had started processing firearms and other items at the scene rather than packaging them up and sending them to the crime laboratory for processing. This procedure, according to the officer, had resulted in a substantially higher rate of recovery of "automated fingerprint identification system (AFIS) quality" prints.

Arguably, the choice of fingerprinting a firearm or swabbing for DNA comes down to being selective in applying both. The likelihood of getting an identifiable fingerprint from the trigger of a pistol is far less than that of finding DNA. However, if a fingerprint is visible on the surface of a gun, it should not be ignored in favor of DNA unless it obviously is not of sufficient quality.

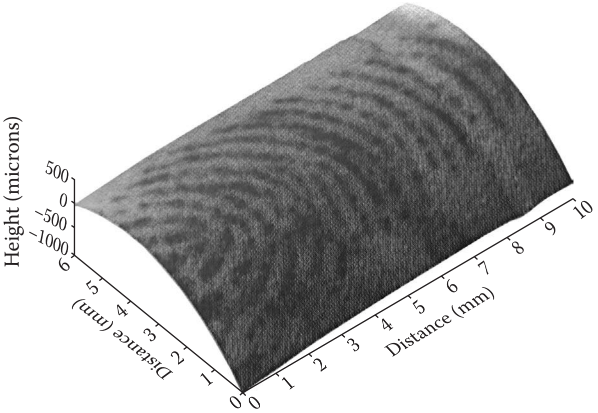

Figure 10.6 Enhanced print on cartridge case.

DNA ON THE TRIGGER DOES THE TRICK

In a homicide in Georgia several years ago, a woman claimed that she and her husband were in their home watching television when a man entered the house through an open garage door, came into the room where they were and shot her husband before fleeing. Officers responding to a 911 call from the woman arrived at the scene and found the woman's husband dead of a single shot to the forehead. The crime scene unit arrived and began processing the scene, ultimately finding a .38 special revolver on the ground just outside the garage.

It was discovered by the investigators that the revolver actually belonged to the woman and that she kept it in her vehicle, which had been parked in the garage. The obvious question for the crime scene unit was what, if any, involvement might the woman have had in the shooting?

The firearms unit identified the bullet recovered from the husband at autopsy. The crime scene unit had, quite appropriately, requested DNA and fingerprint examinations on the revolver. They had swabbed the revolver handles and trigger at the scene and submitted the swabs with the gun, leaving the fingerprint examination for the laboratory.

Although no identifiable fingerprints were found on the revolver, DNA was found that included two contributors—a male and a female. The woman could not be excluded as a contributor of the female fraction (there was no sufficient information for a more definitive conclusion). The husband was excluded as a contributor of the male fraction. Ultimately, an investigation revealed that the husband had recently turned away a transient who had allegedly stopped by while he was doing yard work and requested a job. After nearly a year went by with no further clues, a transient was arrested in a nearby town and a DNA sample was taken. A hit on the CODIS (Combined DNA Index System) database led investigators to reopen the case. Ultimately, the transient was convicted of the murder. Unfortunately, the woman had endured quite a bit of criticism and suspicion in the interim.

Function Testing

Function testing is a standard part of the protocol in a firearms-related incident. It is surprising how frequently this important step is ignored, especially in so-called obvious cases (apparent suicides, officer-involved shootings, etc.). Regardless of the type of case, if a firearm is involved, it should be ascertained that the firearm is functioning properly. This is, of course, a role performed by firearm examiners or police armorers.

Function testing includes not only establishing that a weapon will fire as designed, but also involves things such as establishing trigger pull, checking for modifications, examining for malfunctions, checking for broken/missing parts, and other evidence related to functioning. Trigger pull, in particular, can play into a shooting reconstruction. An extremely light trigger pull, for example, can possibly explain the unintentional firing of a weapon. Excessive trigger pull, on the other hand, can help refute a claim of unintentional firing. The protocol for this testing has been established by the Scientific Working Group for Firearms and Tool Marks (SWGGUN), and that protocol should be used by firearms examiner, particularly in accredited laboratories (American Society of Crime Lab Directors/Laboratory Accreditation Board [ASCLD/LAB], International Standardization Organization/International Electrotechnical Commission [ISO/IEC]). The reader may find the testing protocols at the SWGGUN website: http://www.swggun.org.

TRIGGER PULL HELPS REPUDIATE DEFENDANT'S STORY

A man was shot in the head allegedly as a result of a pistol "going off" as it was being handed to the man by an acquaintance. According to the acquaintance, the two men had been seated inside an apartment discussing "business" when the visitor/decedent asked if he could take a look at the gun his acquaintance had. The acquaintance claimed that he went into the bedroom and retrieved a Jennings .380 semiautomatic pistol that he kept under the mattress and brought it out to show it to the man. He stated that the man was seated on the couch and as he stepped toward him he extended his right hand out with the gun lying in his open palm. He stated that as he did this, the gun "just went off," the exiting bullet striking the seated man.

Investigators found the story questionable to say the least. In the first place, this amounted to a "spontaneous discharge." Secondarily, and equally problematic, the entry wound to the deceased was at the top of his head. The pistol was taken into custody by investigators, submitted to the crime laboratory, and determined to be in working order and to have fired the fatal bullet. Accordingly, murder charges were filed against the gun owner.

The gun owner was absolutely adamant about the "spontaneous discharge" and demanded that his court-appointed attorney seek out an expert who could test the gun. The author was contacted and advised of the request for testing. The author advised the attorney of the unlikely nature of such a premise, but agreed to test the gun. Once the gun was received, it was loaded with a primed case in the chamber, cocked, and shaken and even dropped (although no dropping had been alleged). The gun did not discharge even under more drastic manipulation. The defendant's version of the shooting was simply not supported by the evidence.

In the author's many years of function testing weapons, there have been few instances where defendant's stories of weapons "just going off" were corroborated by function testing. Most of the time, it would appear that when a defendant states that "the gun just went off," it is simply wishful thinking on their part and an effort to somehow shift responsibility away from them. In each case, however, every possible effort must be made to determine if there is any feasible way that the shooting could have happened as a result of mechanical malfunction or other circumstance represented by the defendant.

Testing, when done appropriately and thoroughly, can substantiate the presence of mechanical factors that need to be taken into consideration. Merely cycling the action of a weapon a few times and deeming it operable is not adequate. Tests must be conducted that simulate the reported circumstances of the shooting as closely as possible. If the weapon was dropped, drop tests need to be conducted. If the weapon allegedly fired owing to the hammer being struck by some object, appropriate tests are required. The reader is referred to the SWGGUN website for the appropriate protocol (http://www.swggun.org).

FUNCTION TESTING CORROBORATES DEFENDANTS' STORIES

Case 1

In a shotgun shooting incident, the defendant claimed that he and the victim had been struggling over a shotgun. He said that his right hand was on the forearm of the weapon when the victim grabbed the barrel and yanked it forward causing the defendant's right hand to slide across the hammer. The defendant stated that he did not have his finger on the trigger and that the gun discharged only as a result of the hammer coming back partially and falling.

Function testing focused on whether the weapon would discharge in the manner described by the defendant. A shot shell was cut open and the pellets and powder charge removed. The remaining primed case was inserted into the chamber and the hammer brought back partially and allowed to fall. The weapon was found to fire as evidenced by the discharge of the primer. Based on this testing, the defendant's story could not be refuted.

Case 2

A woman called 911 following a shooting involving her son. The son had a long history of prescription drug abuse and required medication for anxiety attacks. On the day in question, the mother had determined that her son was back to abusing hydrocodone (her prescription for back pain). She hid the hydrocodone in an effort to thwart his taking them. When he realized this, a violent argument ensued.

The mother told police that she and her husband had allowed her son to sleep on a couch outside their bedroom and to keep a .25 caliber semiautomatic pistol under the couch to help "keep him calm" through the nights as a result of him having been attacked by a group of young men several weeks prior. When the son started ransacking their bedroom looking for the hydrocodone, she said she retrieved the pistol and came into the bedroom and sat down in a chair hoping to calm him down. She said that, rather than calming down, he ran over to her and stood over her threatening her, causing her to raise the pistol she had down at her side and order him out of the bedroom. It was then, according to her, that he grabbed her hand causing her to pull back and resulting in the pistol discharging and the bullet striking him in the face and exiting the top of his head, killing him. She said the gun had been put on "safe" before she entered the room. Officers at the scene noted that the safety lever was engaged when they took the gun into custody for submission to the crime laboratory firearms unit for testing.

The pistol was a Raven Arms .25 automatic pistol and, upon examination and testing, was found to have a dysfunctional safety that would allow it to be fired even with the safety on. A check with other firearm examiners revealed this was a fairly well known problem that had been recognized for a number of years. This was significant in the woman's acquittal at trial.

Case 3

A police officer claimed that her weapon, a Glock 9-mm semiautomatic pistol, had discharged as a result of the back door to a residence striking the muzzle as she held it while checking a silent burglary alarm call at the residence. The bullet passed through the door, striking the resident and killing her. The officer had responded to the burglar alarm call unaware that the homeowner had also been called and had arrived first. Apparently, an open back door was responsible for the alarm. It appeared that the homeowner was closing the door from inside as the officer approached from outside.

Several considerations were apparent in analyzing the situation. First of all, the simple physics of the event, as described by the officer, were wrong. If the officer had her finger on the trigger and the muzzle of the gun were impacted, her trigger finger would have been forced forward not backward. Second, if the muzzle of her semiautomatic pistol were struck by the door, the slide would likely have been moved rearward taking the weapon out of battery and making it unfireable. Lastly, if the muzzle of the weapon were against or near the door upon discharge, soot deposits should have been left on the door (there were none).

A reenactment was conducted using a similar door and weapon loaded with a primed case. The weapon was held parallel to the ground with a finger on the trigger with enough pressure to take up the free travel ("slack"). The door was then repeatedly slammed against the muzzle without discharge. The weapon was then loaded with a live round and fired at near contact distance. A heavy soot deposit was produced on the target medium.

When the officer was presented with the test results, she admitted that she had actually fired her weapon as a result of being startled when the door suddenly moved and that the door had never struck her gun. Unfortunately for the officer, this change in stories constituted grounds for dismissal and left the police agency liable for civil action.

Accuracy Determination

Accuracy determination may be required as part of the analysis and reconstruction of a shooting incident. This is particularly true when weapons with telescopic sights fired at long range are involved, but it can also be an issue with other weapons and also at relatively close range. One of the arguments to accepting Lee Harvey Oswald as the lone gunman in the assassination of President John F. Kennedy has to do with the fact that the scope on the rifle allegedly used by Oswald had a misaligned scope. If it could have been confirmed that the scope was misaligned before the shooting, either Oswald would have had to have been extremely lucky or there was another shooter. No such confirmation was ever made.

Accuracy determination is a mechanical assessment only and has nothing to do with establishing the abilities of a suspected shooter. It would be foolhardy indeed to attempt to have a suspect demonstrate their shooting skills or lack thereof. The phrase "If the glove don't fit, you must acquit" comes to mind. By limiting testing to the weapon itself, the investigator can at least determine what the weapon is capable of under the circumstances of the shooting. Whether a defendant would have been capable of carrying out the shooting using that weapon must usually be left up to the jury.

Accuracy determinations are usually best carried out by placing the weapon in a machine rest and using a remote trigger release device. In this way, the human factor is virtually eliminated. Such rests are available for both handguns and long guns. The weapon is set up in the rest, and a suitable target is placed in a position that approximates the incident shot or shots in distance. A minimum of three shots are fired from each distance involved. Then the group spread is noted and recorded.

It may not be necessary to actually fire a weapon to establish accuracy. In a case in which the author was requested to determine the accuracy of a .22-caliber rifle fitted with a scope, it was possible to merely remove the bolt and insert a laser into the bore. Because the shot in question had been fired from a distance of approximately 50 feet, a target could be set up and the laser beam set on the center of the target. With this done and the rifle set up in a machine rest, all that was required to establish accuracy was to look through

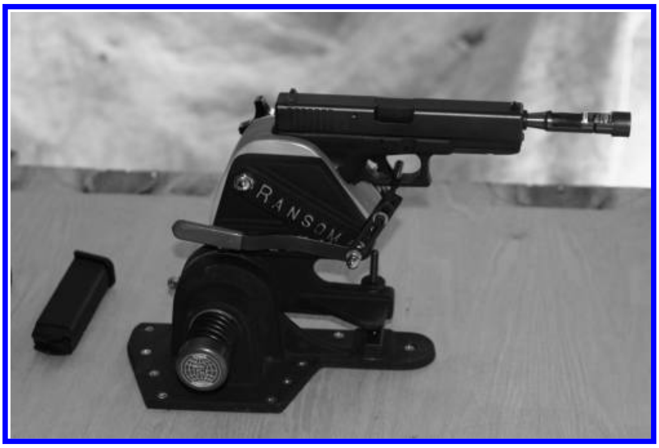

Figure 10.7 Pistol in Ransom Rest with laser bore sight inserted.

the scope. In this instance, the cross hairs of the scope coincided with the laser dot set at the center of the target. Thus, it was determined that the scope was properly aligned. Figure 10.7 illustrates the use of a machine rest and bore laser.

Physical limitations can certainly play into the analysis of a shooting incident. If a person has limited vision, for example, the feasibility of intentionally firing a shot at someone at a significant distance and under low light conditions certainly is raised to question. Other physical limitations, such as limited use of either hand, could be a factor and must be considered as well. These aspects are beyond the scope of the investigator alone and require the expertise of the appropriate medical professionals.

Rate of Fire Determination

Rate of fire for fully automatic weapons can be obtained from the manufacturer and other sources. Rate of fire for other than automatic weapons must be established through testing. However, the results obtained are clearly dependent on the physical capabilities of the individual carrying out the test to a large degree. In other words, such testing is, by nature, subjective. On the other hand, we cannot imagine asking a defendant to demonstrate how rapidly they can fire a particular weapon and have any expectation of reliable results.

If it is necessary to establish the rate of fire of a nonautomatic weapon, one method is to carry out a series of timed firings using more than one individual. In this way, the results obtained can be compared and averaged. While clearly still not eliminating the subjectivity, the results are probably acceptable for use in analyzing most shootings where there is a question as to the feasibility of a certain number of shots having been fired within a given time frame.

A QUESTION OF HOW MANY SHOTS COULD BE FIRED

A moving vehicle is fired upon and the driver is shot dead. There is evidence of two additional shots having been fired. A suspect was arrested and a semiautomatic .22-caliber rifle was seized. The shooter had a limited view that would have required rapid firing and rapid reacquisition of the moving target. The question to be answered was could three shots have been fired at the vehicle during the time that it was in view? To answer this question, it first had to be determined how rapidly the weapon could be fired. Once this was established, knowing how long the vehicle was in view of the shooter permitted determination as to the number of shots that likely could have been fired.

The testing was carried out in an indoor range with the weapon shouldered and a magazine with 10 rounds. Firing commenced upon the start of a timer and continued until all 10 rounds had been fired. Three individuals were involved in the testing. Each individual carried out the firing of 10 rounds three times. The results of all the firings were then averaged. Based on this testing, it was determined that a minimum of four shots could be fired within the time the vehicle was in view. Since only three shots were in question, the testing resolved the issue.

In reporting the results of rate of fire determination, care must be exercised to not overextend the meaning of test results. If the rate of fire was determined to be, say, 3.8 shots/second, and the question was whether four shots could have been fired, it is recommended that the result be rounded down. In other words, in the interest of conservatism, 3.8 shots/second should be reported as 3 shots/second. This conservative approach is based on the inherent subjectivity of the testing.

Exercises

1. Why do identifiable fingerprints seldom show up on firearms?
   Answer: The surfaces that are typically handled on firearms do not lend themselves to retention of fingerprints, and the manner in which firearms are usually handled is not conducive to leaving complete fingerprints.
2. What sort of trace evidence might be left on firearms that could be used to identify an individual who handled the firearm other than fingerprints?
   Answer: DNA can be detected on firearms and used to identify the contributor.
3. When should trigger pull testing be conducted?
   Answer: Trigger pull testing should be a routine part of weapons function testing, because the most frequent claim heard in so-called accidental shooting is “the gun went off.”
4. Why is accuracy determination limited to the mechanical aspects of the weapon only and no consideration is given to shooter skill?
   Answer: There is no objective way to assess shooter skill, given the vested interest the shooter/defendant has and no simple or reliable way to “standardize” the test firing.
5. A vehicle presents a visible target for approximately 8 seconds. A suspect is arrested with a bolt action rifle. Testing indicates a maximum rate of fire of 1.5 rounds per second. Could the shooter have fired six shots into the vehicle within the time frame the target was visible?
   Answer: The rate of fire is multiplied by the available time to determine the maximum number of shots possible.

$$1.5 \text{ shots/second} \times 8 \text{ seconds} = 12 \text{ shots possible}$$

Therefore, six shots are certainly possible.

Suggested Readings

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Gunshot Residue Testing

11

The residue produced by the discharge of a firearm provides potentially important information for the reconstruction of a shooting incident. Locating these residues can allow determinations of firearm-to-target distances to be approximated as well as indicate who might have been in proximity to a firearm discharge. As with any type of forensic evidence, it is important to recognize both the capabilities and the limitations of gunshot residue (GSR). A dramatic display of the production of gunshot residue is seen in Figure 11.1.

GSR Sources

The general term "gunshot residue" is frequently inappropriately used when referring to singular components of firearm discharge. This is somewhat understandable because GSR actually includes a number of different components. These components include

- Primer residue
- Gunpowder particles (partially burned and unburned)
- Stabilizers
- Plasticizers
- Combustion products ("soot" or smoke)

The presence of some or all of these components permits the investigator to make certain statements regarding the probability of someone firing a weapon, being in close proximity to a weapon that was fired, handling a weapon or otherwise coming into contact with GSR, as well as approximating the muzzle-to-target distance. It is the multiplicity of explanations that have led some to reject GSR testing entirely. However, when understood and applied properly, the presence of GSR is worthy of consideration in a shooting reconstruction and can, in many instances, be the lynchpin in a case.

Persistence of Primer Residue

A reasonable analogy of primer residue deposition might be made with talcum powder. If one imagines a light dusting of the back of the hand with talcum powder and then putting on a glove or thrusting the hand into a pocket, it is easy to visualize how transient primer residue can be. This is, of course, to say nothing of a vigorous washing of the hand with hot, soapy water. Talcum powder, like primer residue, would be expected to be more persistent when deposited on the surface of, for example, loose-weaved garments. As might be predicted, the smoother/harder a substrate is, the less adherent we would expect it to

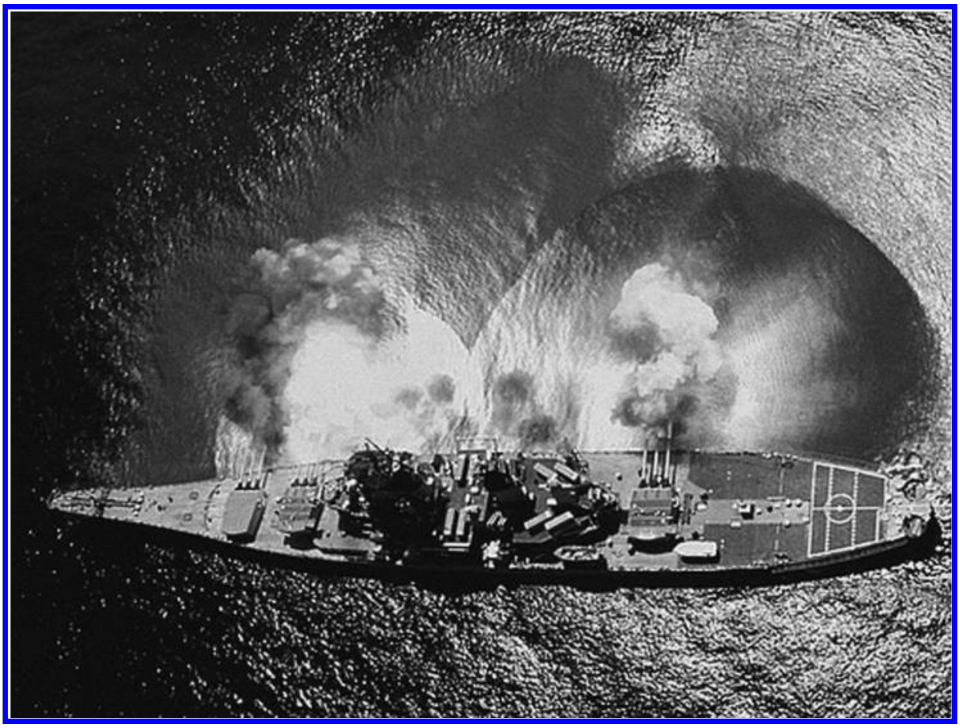

Figure 11.1 **(See color insert.)** Ultimate GSR (USS IOWA muzzle blast).

be to primer residue. Likewise, the greater the degree of exposure to the elements, the less likely primer residue will persist. However, the familiar watchword "One test is worth 1000 excuses" applies here as well as in many other areas of forensic science.

Primer Residues and Shooter Determination

Primers are responsible for initiating the combustion of the powder charge in a cartridge or shot shell. In metallic cartridges, the priming mixture is either found in the annular rim (rim fire cartridges) or in a cup seated in a recess in the head of the cartridge case (center fire cartridges). Shot shells also utilize a center fire primer. Most primers consist of a mixture of compounds containing lead (Pb), barium (Ba), and antimony (Sb). A notable exception is found in lead-free primers that are gaining popularity owing to health and environmental concerns. If lead-free primers are known or suspected to have been used, the laboratory needs to be alerted to this. Ammunition produced using lead-free primers is available from a number of manufacturers including Blount Industries (CCI), Federal, Winchester, and Remington.

When a firearm is discharged, primer residues—along with other components of GSR—will emanate from the muzzle, the breech, and/or the cylinder gap depending on the type of weapon involved. The production of GSR resulting from discharge of a revolver is shown in Figure 11.2.

The components of primer residue produce a plume that can be deposited on the hands of a shooter as well as on anything within close proximity. Historically, sampling for primer

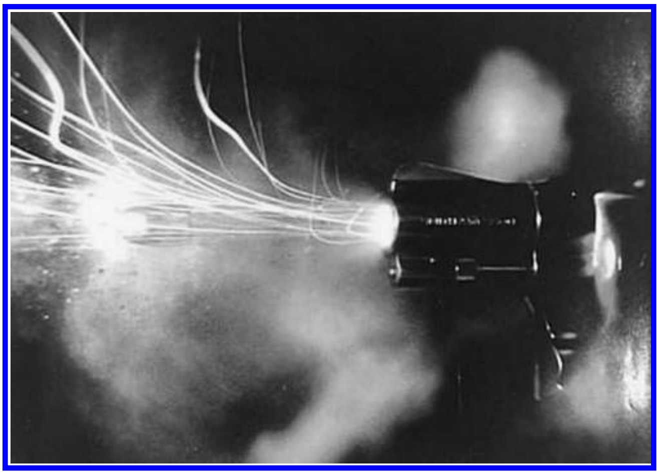

Figure 11.2 **(See color insert.)** Typical revolver discharge products.

residues has been limited to the palms and backs of the suspected shooter's hands. Because there is a plume of these residues produced, it is reasonable to assume that they might also be deposited on other areas of the shooter's body, such as the face. Anyone who has ever used fingerprint powder or sprayed paint in a confined space has experienced the deposition of residue within the nostrils and on the face. Thus, including the face, facial hair, and inside the nostrils might be a consideration when sampling a suspect. Many agencies have recognized this and do appropriate sampling.

In any event, finding primer residues on a suspect must not be construed to mean that the suspect had to have fired a weapon as opposed to merely being in close proximity when a weapon was discharged, handling a weapon that had residues on it, or otherwise coming into contact with a source of primer residues. Additionally, suppose an officer has drawn his weapon during an arrest, reholstered the weapon, and then handcuffed the suspect. Could the officer have gotten primer residues on his hands upon handling his weapon and then transferred them to the suspect during the handcuffing? Theoretically, the answer has to be yes. It is a widely accepted fact that handling a weapon can result in the transfer of residue from the gun to the hands. Likewise, a transfer due to contact between any two surfaces can result.

For purposes of reconstructing a shooting, one must be careful in concluding that an individual fired a gun as opposed to any of these other scenarios that have been presented. The distinction between homicide and suicide is sometimes attempted based on the presence or absence of primer residues. The fallacy in attempting this lies in the fact that if the victim of a gunshot has primer residues on their hands, it could have resulted from being shot just as easily as by having fired the weapon.

An additional problem has to do with the sampling technique typically used. The method of choice for conducting primer residue analysis is scanning electron microscopy (SEM) coupled with x-ray fluorescence spectroscopy (XRF). Confirmation of a particle as originating from the sampling is done using small aluminum disks with an adhesive side. The disks (stubs) are repeatedly pressed against the skin of the hands in an effort to transfer the residue from the hands to the disk via the adhesive on the disk. In sampling, it is difficult to distinguish where the palm stops and the back of the hand starts in many instances. Thus a sample collected "from the palm" may include residues from the back of the hand

and vice versa. Also, there are no generally accepted guidelines as to how many times the adhesive disk is applied to the subject's hands. Is it once per specific area or multiple times? If multiple times, how many? What is done if there is obvious foreign residue present (e.g., dirt, blood, grease)? These questions, and some others, have caused some agencies to stop doing the testing at all. Again, it is this author's opinion that there is a time and place for this type of testing, just not every time and every place.

The laboratory analysis of GSR (primer residue) is best accomplished using computer-controlled scanning electron microscopy coupled with XRF (CCSEM–XRF). This technique allows definitive results to be obtained through the relatively rapid examination of thousands of particles. As previously suggested, consideration might be given to the eyebrows and any other facial hair present. Figures 11.3 and 11.4 illustrate the results that may be obtained.

Some laboratories, owing to equipment cost considerations, rely on flameless atomic absorption spectroscopy for the analysis of primer residues. This technique is less specific and is prone to inconclusive results. As this was the method that most laboratories initially implemented, GSR (primer residue) testing developed somewhat of a bad name in many areas of the country. Some investigators and even entire agencies stopped using the test as a result. This disparity in confidence has yet to be totally resolved.

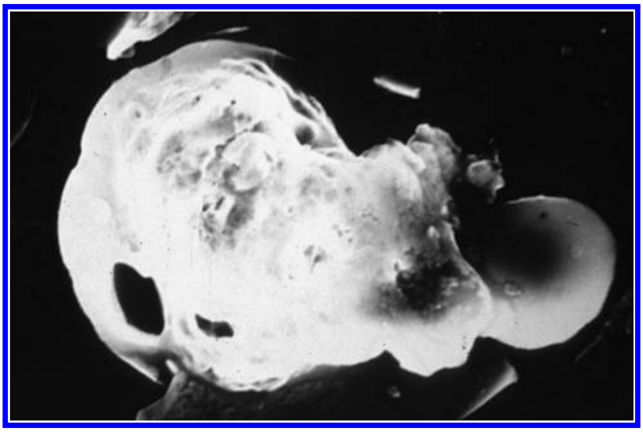

Figure 11.3 SEM image of a primer residue particle.

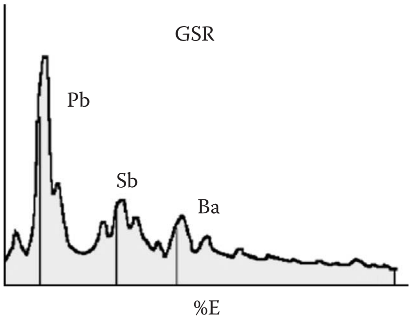

Figure 11.4 Typical x-ray fluorescence scan for primer residue particle containing lead, barium, and antimony.

An in-depth discussion of the analytical techniques is beyond the scope of this text. Interested persons should refer to any of a number of excellent reference works on the subject. Simply doing an Internet search will also provide additional information on the topic.

For purposes of shooting reconstruction, our interest is in taking the results and applying them to the question at hand. However, an understanding of the capabilities and the limitations of this evidence is essential. As already pointed out, sampling is not a definitive process for the most part. Another problem has to do with the time that has elapsed since the discharge of the weapon and the sampling. It is generally accepted that primer residues do not persist beyond about 4 hours of "normal activity." This time frame can be extended through the sensitivity available with modern CCSEM–XRF equipment. Ten to twelve hours of activity is the generally accepted upper limit for collecting samples for CCSEM–XRF testing.

On the other hand, the sensitivity of CCSEM–XRF brings with it some questions as well. If the technique can locate and identify one or two so-called unique (many agencies apply the term "indicative" instead) particles containing lead, antimony, and barium, the question as to the source of these particles must come up. The example of transfer from the hands of an officer to a suspect during arrest comes to mind once again. All these issues are tied to the distrust that some agencies have in the test results.

The use of CCSEM–XRF involves the location and identification of particles that are either considered characteristic of primer residue or unique to primer residue. These particles are mostly spherical and in the 1–10 μm range, but nonspheroidal particles are not uncommon. The categories of characteristic and unique particles are as follows:

- Particles considered "indicative" of GSR
  - Lead–Antimony (Pb–Sb)
  - Lead–Barium (Pb–Ba)
  - Antimony–Barium (Sb–Ba)
  - Antimony (Sb)
  - Barium (Ba)
  - Barium–Calcium–Silicon (Ba–Ca–Si) with trace of Sulfur (S)
- Particles considered "characteristic" of GSR
  - Lead–Barium–Antimony (Pb–Ba–Sb) in a single particle

Although most analysts consider three-component spheroidal particles to only be found in primer residue, the more conservative terminology is generally applied.

The results of CCSEM–XRF typically include a listing of the numbers of particles of each particular composition. Only the presence of particles containing lead, barium, and antimony are taken to be "conclusive" with regard to the presence of primer residue. Most laboratories require the identification of at least three such particles. Some laboratories will report confirmation of primer residue on the basis of a single "characteristic" particle having been located and identified.

What must be kept in the forefront is deciding when testing is important (i.e., when it should be used). It should be apparent from our discussion of all the various considerations that primer testing is inappropriate for victims of gunshots and cannot distinguish between homicide and suicide. So when would it be appropriate? It is appropriate when an individual of interest has no reason whatsoever to have primer residue present on his/her person.

Case 1. GSR Testing Solves a Crime

Two young males were sharing an apartment back in the early 1980s in Arizona. They were college students, and each had his own bedroom. One evening, one of the men called authorities and reported that his roommate had apparently committed suicide. Officers arrived to find the dead man on the floor of his bedroom with a revolver lying at his side.

Upon being questioned, the reporting person stated that he had been in his own room studying when he heard a loud noise. He stated that he came to his roommate's closed door, called out, and then entered to observe the man lying on the floor. He stated that he then went straight to the telephone in the living room and called for help. He said that he did not touch the dead man because of the obvious mortal wound to the head.

The investigator asked the man how long did it take from the time he heard the "loud noise" until he actually entered the dead man's bedroom. The man replied that it was several minutes. The investigator then asked the man if he touched the gun, and he stated that he had not. The investigator then asked the man if he had fired a weapon anytime that day before the shooting and the man again said no. Finally, the investigator asked the man if he had been around any weapons being fired that day or had handled any weapons. Once the man answered no to that question, the investigator advised him that he would like to do a GSR test on him.

The results of GSR testing on samples taken from the palms and backs of both hands by SEM–XRF indicated the presence of numerous spheroidal particles consisting of lead, antimony, and barium. The laboratory report stated that this was "indicative of having fired a weapon, been in close proximity to a weapon being fired, having handled a weapon or otherwise come in contact with primer residue." Because the investigator's questions had eliminated anything other than the man having fired the fatal shot, this finding was of considerable value to the case. When confronted with the evidence, the man finally confessed to having murdered his roommate.

Case 2. GSR Testing Inappropriately Applied

Police in a rural community in West Virginia respond to a call from a husband who claims he came home to find his wife shot to death. The woman is found lying on the floor just outside their bedroom with a devastating wound to the forehead that clearly was produced by a shotgun. A shotgun is found on the floor nearby. Blood and tissue on the walls and ceiling indicates the woman was standing upright when she was shot.

Several red flags go up in the investigator's mind immediately. First of all, women shoot themselves in the head only very infrequently. Second, there is no apparent means for her to have reached the trigger to fire the gun and hit her in the forehead. The shooting appears to be the result of foul play to the investigator. In an effort to settle the question of homicide versus suicide, the investigator has the crime scene take samples from the woman's hands for GSR testing. This request is ill advised at best. Because the woman is the victim of a gunshot injury, it is expected that she will have GSR on her. On the other hand, not finding residue cannot be construed to prove anything. Like any negative evidence, "absence of evidence is not evidence of absence."

In this particular case, not only was conducting the test inappropriate, the interpretation of the results was inappropriate as well. The results were positive, as expected. However, the investigator interpreted the standard reporting verbiage ("indicative of firing a weapon, being in close proximity to a weapon during discharge, or handling a weapon") as an indication of suicide. Although GSR testing alone cannot exclude suicide, it in no way promotes it.

Ultimately, the husband was determined to have been responsible, although he claimed it had been unintentional and that he had panicked. If anyone should have been tested for GSR in this case, it should have been the husband, particularly since he claimed to have been elsewhere during the shooting. The confusion that resulted by testing the woman was totally unnecessary and could have been avoided by following the general rule that victims of shootings need not be tested.

Case 3. Contact with a Source of GSR

Two gang members do a drive-by shooting that results in the death of a rival street gang member. Both the driver and the front passenger fire shots from inside the vehicle they are driving. Upon their return back to their turf, a fellow gang member (uninvolved in the shooting earlier) asks to borrow the vehicle to go purchase some beer and cigarettes. As he is driving to the convenience store, an officer spots the vehicle and proceeds to stop it because it matched the description of the vehicle used in the drive-by shooting a few hours earlier. The officer requests permission from the driver to take hand samples for GSR testing. The driver complies, no doubt recognizing that he was not involved in a shooting that day and would, hence, not test positive. Following laboratory analysis in which several particles indicative of primer residue were found on the palms of both hands, police arrested the man and charged him in the murder. Subsequent testing of the steering wheel, gear shifter, and inside door handle revealed the presence of primer residue particles. Further information obtained by investigators implicated the real shooters, and the man originally arrested was cleared of the drive-by shooting.

One question that frequently comes up is whether anything other than primer residue could produce positive test results. Certainly, there are numerous environmental sources for lead, barium, and antimony. There are also various sources associated with manufactured products and pyrotechnics. Some years back, a study found that the disk brake pads from Ferrari automobiles produced three-component particles that might be confused with primer residue. Obviously, the first thought would be how many people in the United States drive Ferraris? That aside, most analysts agree the brake pad sourced particles can be distinguished from primer sourced particles morphologically (i.e., by shape as seen in an SEM image).

Some caution must be exercised in the interpretation of positive results for primer residue even with SEM, however. William Matty, in an article published in the *AFTE Journal* in January of 1991, described finding spherical lead particles on test specimens that were produced by the impact of lead bullets with a vehicle. These particles at first appeared to be primer-based lead particles.

In summary, the identification of primer residues, when applied under appropriate circumstances, is a reliable and scientifically sound analytical technique that can assist the investigator in the reconstruction of a shooting. The results obtained must, however, be taken within the context in which they have been reported: indicative of possibly firing a weapon, being in close proximity to the discharge of a weapon, or having handled a weapon. Consideration to other possible sources of cross-transfer must also be considered.

Muzzle-to-Target Distance Approximation Testing—Inanimate Objects

Competitive shooters typically fire ammunition of their own making (hand loads) so that they can maximize the performance for the particular distance they are shooting and the particular barrel length. Commercial ammunition, on the other hand, must accommodate a wide range of conditions and weapons (i.e., barrel lengths). Manufacturers incorporate more than enough gunpowder to ensure that bullets will be propelled from barrels ranging from 2 to 30 inches, for example. The bottom line is that, with more than enough gunpowder present for all typical situations, not all the gunpowder will be consumed during discharge.

Unburned and partially burned gunpowder particles will exit the muzzle in a conical distribution upon firing. Persons/objects that happen to be within a few feet of the muzzle will be struck by these particles. In some instances, the powder particles can travel unexpected distances. Gunpowder particles can also sometimes pass through various objects such as fabric or human tissue before coming to rest. Figures 11.5 through 11.7 show the relative size of gunpowder particles that might be found.

The horizontal distance traveled by gunpowder particles depends, to a large extent, on the morphology or shape of the particles and their mass (given equal initial velocities). Handgun powder is found in spherical (ball), flattened ball, and disk or flake configurations. Rifle powder also includes tubular configurations. Black powder and black powder substitutes such as Pyrodex have irregular shapes.

Two forces act on gunpowder particles in flight as for any object in motion: gravity and air friction. Both of these forces work to slow down and "pull down" the particles. The greater the mass and the more aerodynamic the shape of the particle, the greater the

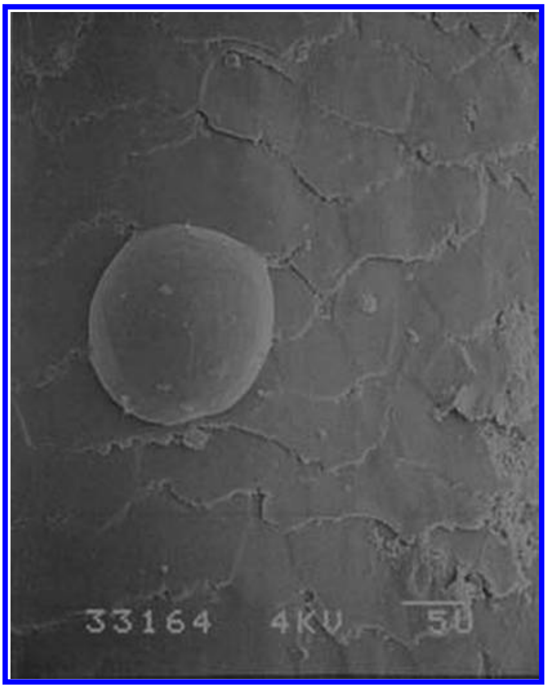

Figure 11.5 Gunpowder particle on skin.

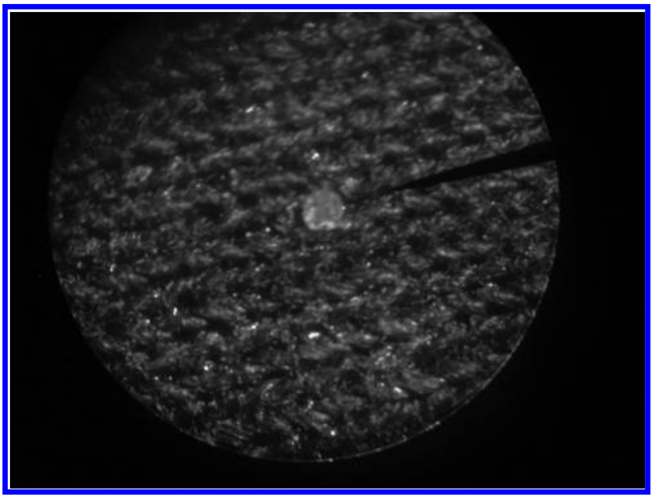

Figure 11.6 Gunpowder particle on a shirt.

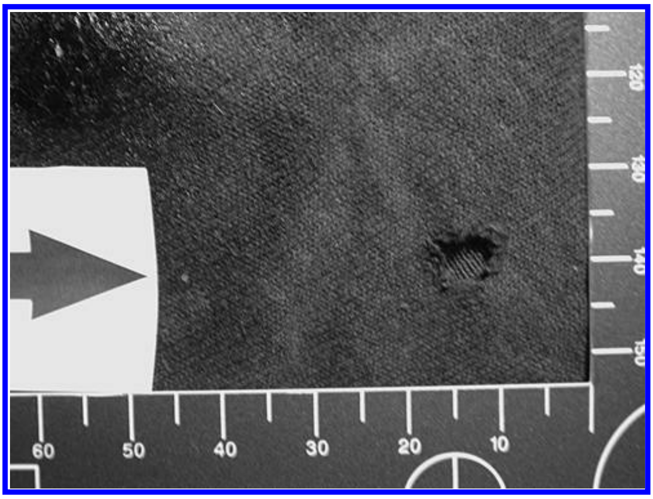

Figure 11.7 Bullet hole in cloth; gunpowder particle.

horizontal distance that would be traveled (for the same initial velocity). A good analogy that can be made would be to compare the distance that one could throw a volleyball as compared to a Frisbee. Thus, all else being equal, we expect ball powder to travel the farthest of the various powder shapes. In the author's experience, individual grains of ball powder can sometimes travel as far as about 20 feet from the muzzle.

As a general rule of thumb, if a person is within an arm's length or less of the muzzle of a firearm, we should consider the possibility of finding gunpowder particles on them (clothing and/or skin). The estimation of muzzle-to-target distance involves carrying out test firings at measured distances in order to establish a range of distances into which the evidence falls. The presence of intermediary targets (i.e., pillows, clothing, doors, windows, hair), physical contact or other activity (i.e., shaking, rubbing, washing) can prevent powder deposition or dislodge particles that were initially deposited.

Articles of clothing and other inanimate objects must be carefully examined microscopically for the presence of visible powder particles. One useful method for documenting their presence is to use a clear plastic overlay sheet that is marked with a marker pen for each powder particle found. This results in a record of not only the locations but the pattern shape and density before chemical testing. A comparison can then be made between the visual results and the results of chemical testing. It is not uncommon for chemical testing to reveal the presence of powder residue that was not microscopically visible. It is also possible for powder particles to be visible but not respond to chemical testing. This is particularly true when blood is present.

The combination of blood and dark material can make it difficult to locate powder particles. One option is to use infrared film to photograph the area of interest. The infrared film will frequently allow the powder particles to appear dark against a light background. This provides an alternative to the tedious process of using a clear plastic overlay to manually mark each particle as previously described. An example of the use of infrared photography of gunpowder particles on a dark garment with blood present is shown in Figure 11.8.

Chemical testing involves testing for the presence of nitrites, the combustion product of nitrates (gunpowder), and lead residues from the primer and/or bullet. The test most often used for nitrites is the Griess test or some modification thereof. The testing is done in the laboratory. The firearm examiner or criminalist carries out testing on the evidence and then on test panels produced using the same weapon and ammunition like that used in the shooting under investigation. A typical result obtained for a test panel is shown in Figure 11.9.

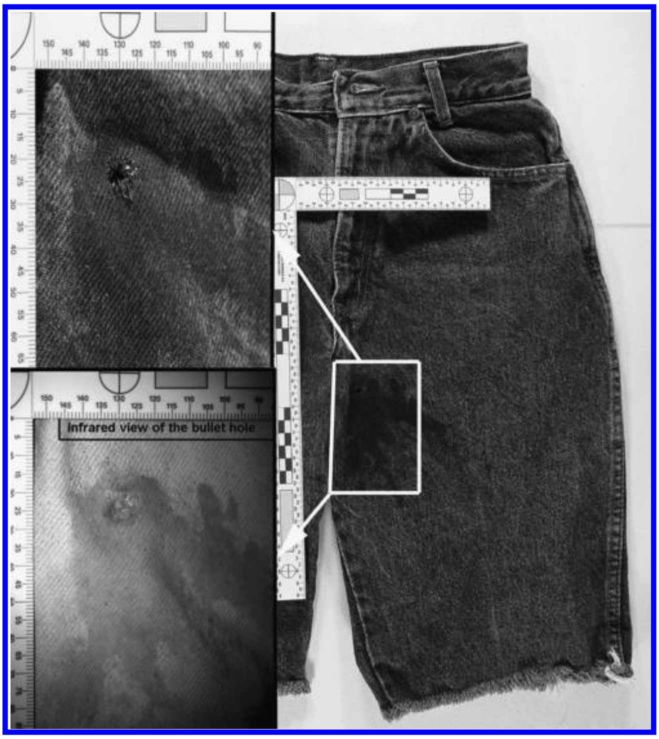

Figure 11.8 Infrared view of GSR.

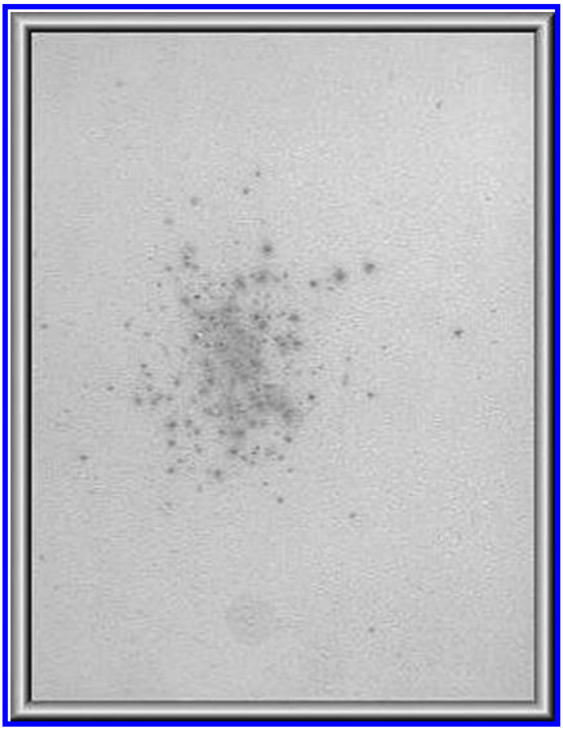

Figure 11.9 (See color insert.) Griess test for nitrites.

The presence of vaporous and particulate lead on inanimate targets provides additional insight into the approximate muzzle-to-target distance. Vaporous lead may be contributed by the primer, the bullet, or the interior surfaces of gun barrels contaminated with lead. Particulate lead originates from bullets and contaminated barrels. The test typically used for vaporous and particulate lead is the sodium rhodizonate test. This is also a chemical test that is usually carried out in a laboratory environment. The presence of vaporous lead is indicative of a relatively close-range shot, the approximate distance of which must be established through the same kind of testing regimen as for the nitrite test. It should also be noted that firing weapons with lead-free primers can still produce positive sodium rhodizonate tests if standard lead-based ammunition was ever previously fired. A typical sodium rhodizonate reaction is shown in Figure 11.10.

A word of caution is in order concerning visual comparisons of residues and distance assessments at shooting scenes. Different brands of ammunition can produce markedly different residue patterns for the same weapon fired at the same distance. This can be seen in Figure 11.11. Unless the investigator is certain that the same brand of ammunition was used for all shots producing visible residues, he should be cautious about presuming one shot was fired from a different distance than another shot without additional information.

In the author's experience, particulate lead is a nonreproducible phenomenon with regard to pattern and distribution. Testing associated with past casework has shown widely varying and contradictory results. Some closer shots produced patterns of particulate lead of greater diameter than shots farther away and vice versa. For that reason, it is

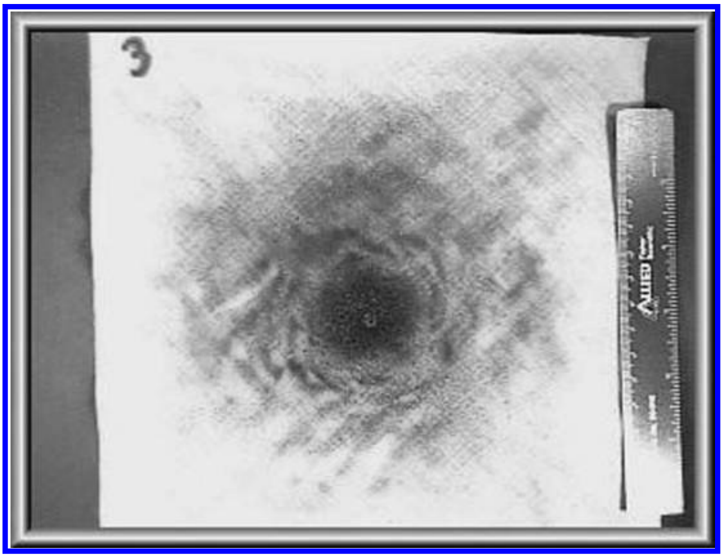

Figure 11.10 **(See color insert.)** Sodium rhodizonate test for vaporous lead.

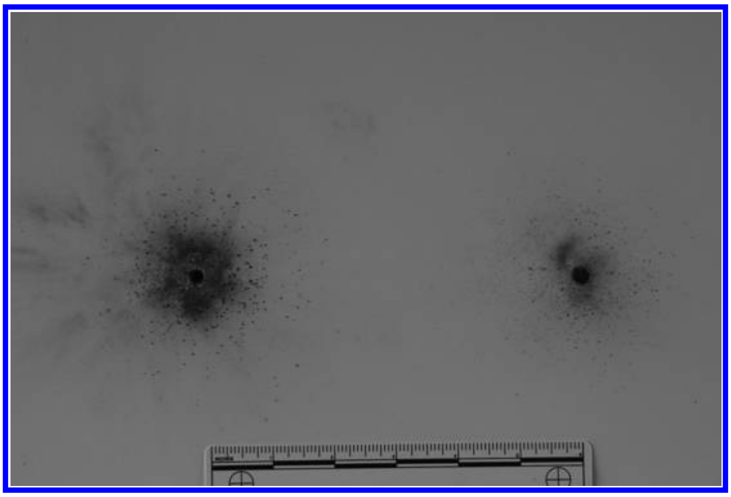

Figure 11.11 Soot residue resulting from different brand cartridges (same shot distance).

recommended that attempting to relate shot distance to a pattern of particulate lead be avoided. It is reasonable, however, to base some approximation of the maximum possible muzzle-to-target distance on the presence of particulate lead in some cases. The sodium rhodizonate test identifies particulate lead as a pinpoint response as opposed to a cloud or haze for the vaporous lead response. For the specific details of carrying out the sodium rhodizonate test, as well as the various forms of the Griess test, the reader is encouraged to consult one of the many excellent references that are available on the subject.

If at all possible, testing should include panels taken from the actual evidence garment or object because different surface textures, thicknesses, etc., can have a significant effect on the deposition pattern obtained. If this is not feasible, a similar material may be used as a substitute. If there is only a limited amount of evidence material available, the initial test firing can be done using 12-inch squares of white cotton twill. Once an approximate muzzle-to-target distance range has been established, a panel from the evidence may be used to confirm the results obtained with the cotton twill.

As with primer residue analysis, the shooting reconstructionist will consider and use the results of muzzle-to-target distance approximation testing. When no pattern of residues is found to be present on items of evidence or when there is a complete absence of residue, it is only possible to establish a maximum range for residue deposition. For example, suppose a victim's shirt is tested and no gunpowder particles are found. Assuming that gunpowder particles were not originally present and then dislodged or that no intervening target blocked the particles, the conclusion would be that the muzzle of the incident firearm was beyond the distance at which gunpowder particles would be able to travel. The weapon, ammunition, and target material would then be used to establish what that maximum distance would be.

If gunpowder particles are identified but an identifiable pattern is not present, all that can be said is that the shot was within the maximum distance at which that weapon and ammunition combination would be expected to leave gunpowder particles under the conditions of the shooting. Once again, this distance would have to be established through test firing.

The appearance of a soot pattern is dependent on the orientation of the firearm, as illustrated in Figure 11.12.

In the old World War II photograph of a German artillery piece being fired in Figure 11.13 the number of barrel lands/grooves can be determined from the smoke pattern (there are 12). The author has occasionally seen this type of pattern on cloth objects shot through at close range.

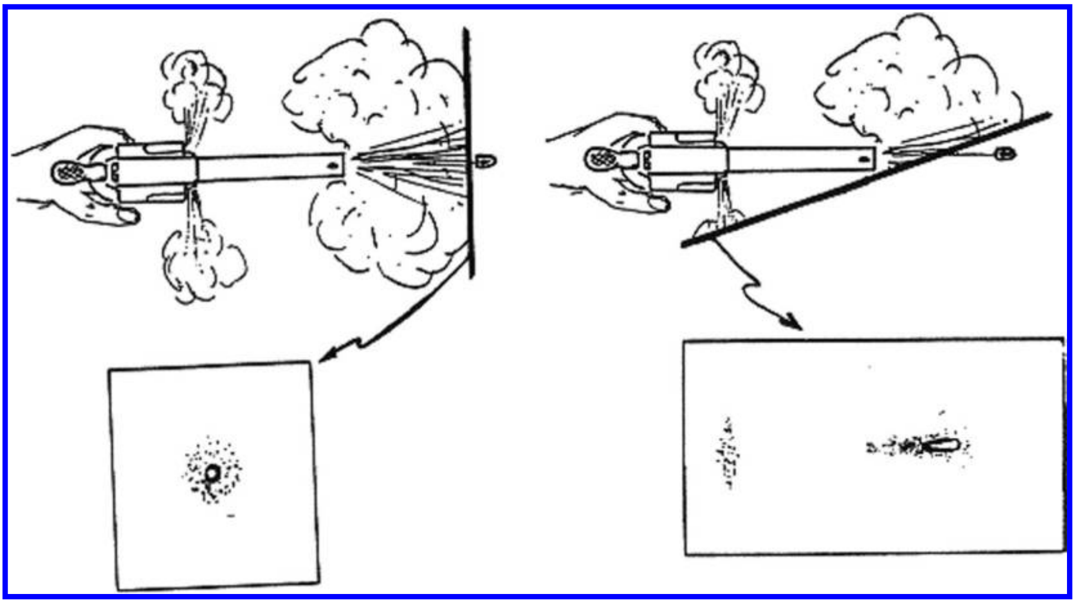

Figure 11.12 GSR orientation.

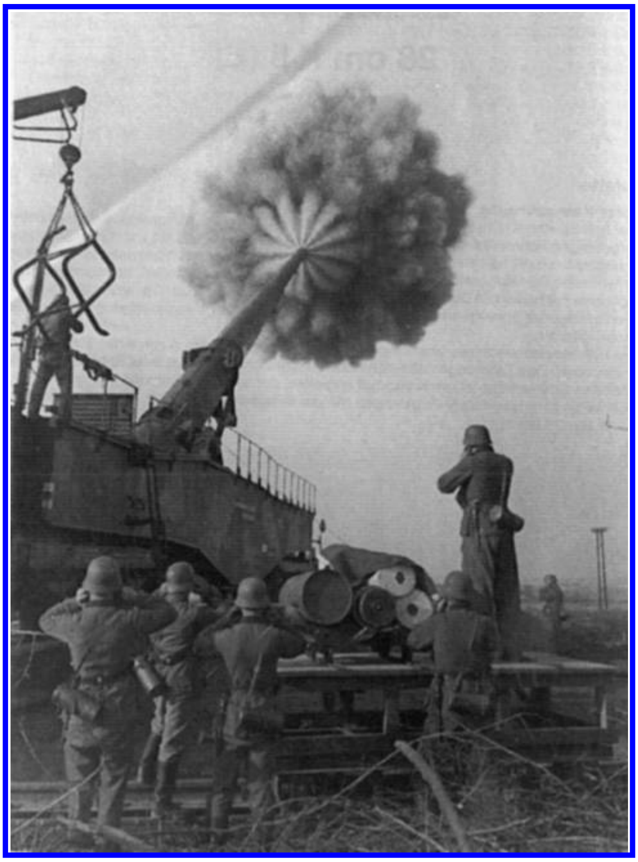

Figure 11.13 Smoke residue shows rifling characteristics.

Collection of GSR from Fixed Inanimate Objects

GSR can and should be located and lifted from fixed inanimate objects such as windshield glass, vehicle body panels, building doors, and walls. The procedure for collecting GSR from objects such as vehicle glass, vehicle exterior and interior surfaces, doors, and walls is the same as the transfer method used for garments. The procedure relies on there being a greater affinity of the GSR for a damp piece of filter paper than whatever substrate it was originally deposited on. Obviously, there will be varying degrees to which this works and, in some instances, it does not work very well (such as when the substrate is a very bulky, loose-knit material). One should make no presumptions, however, as “one test is worth 1000 excuses.”

The procedure is:

1. Visually inspect the area around a bullet hole for the presence of GSR using a hand lens. Make note of any possible GSR observed to be present.
2. Take a piece of filter paper of sufficient diameter to cover the area of interest (suitable paper diameters range from about 4 inches to about 18 inches) and moisten it by spraying it with a spray bottle of 5% nitric acid (distilled water can be eliminate if necessary). The paper should be damp but not dripping wet.

3. Press the damp filter paper against the surface to be tested, using a rubber fingerprint roller to apply pressure and smooth out any raised areas. As an alternative, one can use their gloved hands to press out the filter paper. The paper should be marked to designate its orientation on the object being tested.
4. After allowing a few seconds of contact, carefully peel the paper off the object and place the paper in a safe place, contact side up, to air-dry for transport back to the laboratory.

In the event that the test paper will be submitted to the laboratory or shipped elsewhere, it should be taped contact side up in a shallow box (such as a pizza box). A second piece of filter paper should then be taped on top of the test sheet (after drying the test sheet) so that GSR particles are not lost in handling.

The test paper may be tested according to the Griess test procedures for nitrates and the sodium rhodizonate test procedures for lead residues. Patterns of nitrates obtained are then compared to test firings from measured distances using the weapon and ammunition components like those involved. Likewise, positive sodium rhodizonate responses for lead are compared to known samples. From these tests, an approximate muzzle-to-target distance may be determined.

Muzzle-to-Target Distance Approximation Testing—Human Tissue

Gunpowder particles exit the muzzle at a high rate of speed. These particles are hot even to the extent of being on fire as a result of discharge. When the particles strike the skin, there are several possible occurrences: they can penetrate the skin, they can produce a bruise, or they can cause a burn. The result appears as a series of dark spots around the margins of the wound known as stippling. The density and pattern diameter of powder stippling provides a means for approximating muzzle-to-target distance.

Typically, laboratory analysts work with forensic pathologists and rely on one another in approximating the muzzle-to-target distance where a pattern of powder stippling has been produced. The pathologist measures and photographs the stippling pattern, and the firearm examiner or criminalist carries out test firing in order to make an approximation of the range of the shot involved.

A suitable medium must be selected for recording the test stippling patterns at various distances. Over the years, various media have been used ranging from painted ceiling tile to pig skin. The idea is to have a way of duplicating the stippling effect using something other than human tissue. The author has used foam board for this purpose for many years. Foam board consists of a thin sheet of Styrofoam sandwiched between two sheets of poster board. Foam board is sold in office supply stores and craft stores mainly for use in making poster presentations. Powder particles marking or indenting the surface of the foam board are equated to producing stippling. Test results in numerous cases the author has been involved in have shown this to be a reasonable representation.

As already discussed on the section “Shotgun Pattern Testing,” Kraft paper is preferable at close ranges where muzzle blast is a concern because it will not break apart like the foam board will. Once again, the assumption is made that if the Kraft paper is marked or indented by a powder particle, that is the equivalent of stippling having been produced. As discussed earlier in this text, plastic sheet is also useful for representing stippling (see Hueske 2011).

Stippling patterns, as well as soot residue pattern shapes, can provide information as to the orientation of a weapon at the time of discharge. Circular patterns indicate a more or less straight-on shot, whereas angular shots are exemplified by elliptical patterns. Additionally, contact and near-contact shots can produce soot patterns that define the orientation of some semiautomatic hand guns. For example, the gap between the slide and the frame and the opening in the slide for the recoil spring rod allow soot to exit and be deposited on nearby surfaces. As always, testing needs to be carried out to confirm any hypothesis put forth. Typical soot and stippling patterns that might be seen are shown in Figures 11.14 through 11.16.

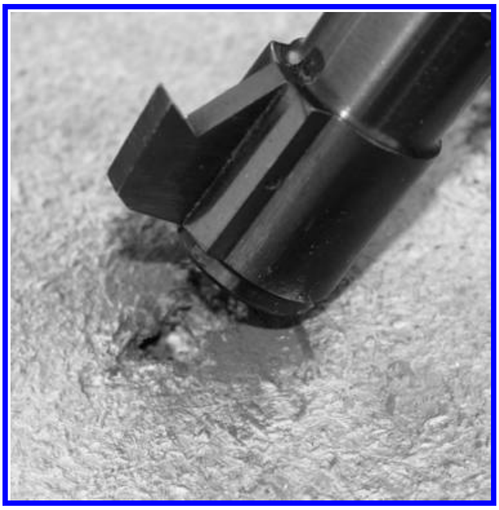

Figure 11.14 Angular shot with semiautomatic pistol.

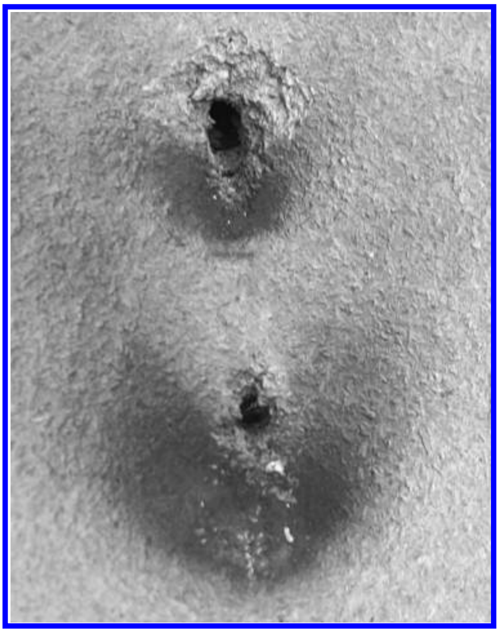

Figure 11.15 Asymmetrical soot deposits produced by angular shots.

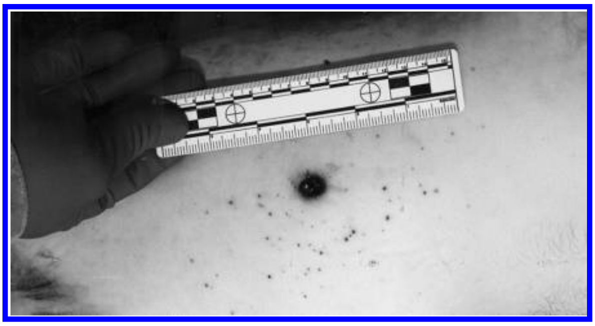

Figure 11.16 Powder stippling on skin (through clothing).

Stippling Discredits Officer's Version of Shooting

An officer responding to a domestic disturbance call in an upscale neighborhood during the noon hour exited her patrol unit, and she and her partner knocked on the front door. They were greeted by the homeowner who exited the residence and came out on the front porch to speak with the officers. The man was obviously highly agitated and began to curse in a loud voice and demand that the officers leave. The female officer took a position to the left rear of the man while her partner stood directly in front of the man. As the man started to move toward the officer in front of him, the officer began giving him verbal commands to halt. When the man failed to comply, the officer kicked him in the midsection. The man doubled over momentarily and then resumed moving toward the officer, ignoring additional verbal commands.

The officer then attempted to kick the man in the left knee but lost his balance and went to the ground. As he went down, he drew his weapon. The officer pointed the weapon up at the man as the officer sat on the ground below him. The man then grabbed the officer's weapon by the barrel. At this point, the female officer stated that she struck the man in the head with her pistol, causing it to discharge. The bullet entered the back of the man's neck just below the base of the skull. The bullet penetrated the brain stem. The man was killed instantly.

In reviewing the case, police investigators found the officer's statement as to how the shooting had taken place inconsistent with the physical evidence. According to the autopsy report, there was an elliptical stippling pattern around the wound to the back of the man's neck. This pattern was oriented 9 o'clock to 3 o'clock with the majority of the stippling toward the 3 o'clock position. The pattern measured approximately 2 by 3 inches. Laboratory testing indicated a muzzle-to-target distance of approximately 8–10 inches. This simply did not comport with the officer's story that the discharge resulted from impact of the weapon with the decedent's head. Upon being confronted with the evidence, the officer admitted that she unintentionally discharged the weapon as a result of having been startled.

Powder Impacts to Headrest of Truck Conflict with "Victim's" Account

A man (RP) called police to report that another man driving a small, black car had pulled next to his pickup while RP was stopped at a traffic light. RP claimed that just before the light had turned green, the man fired a shot through the open windows of RP's Ford pickup narrowly missing him, the bullet passing through the driver headrest. When the crime scene investigator arrived, he examined the headrest with the through-and-through bullet hole and used a laser trajectory rod to establish the trajectory through the headrest. The investigator also took photographs of the headrest, all of which are depicted in Figures 11.17 through 11.20.

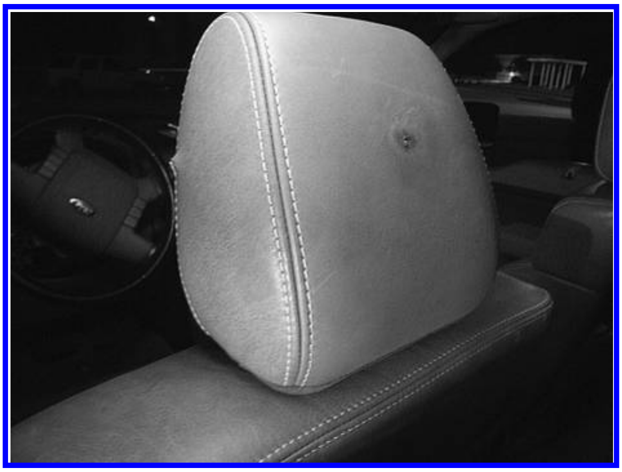

Figure 11.17 Headrest with bullet entry–exit.

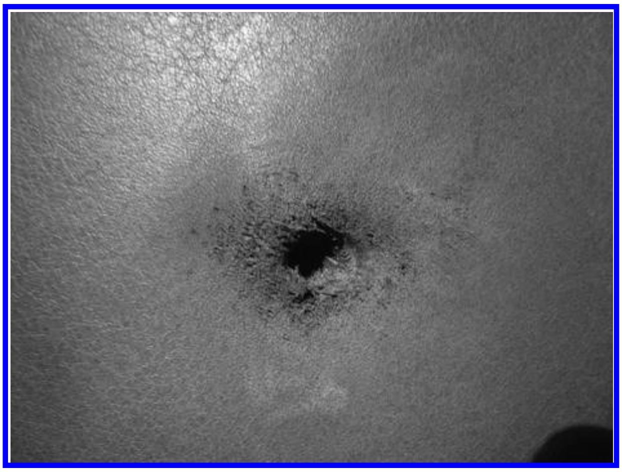

Figure 11.18 Close-up of bullet entry into headrest.

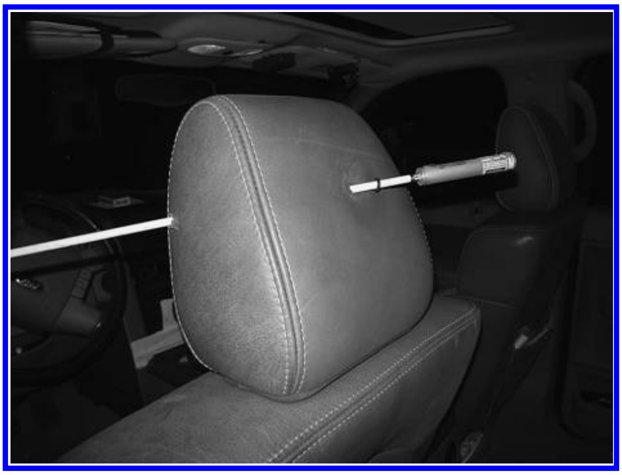

Figure 11.19 Trajectory determination.

Figure 11.20 **(See color insert.)** Laser termination.

As is evident from the close-up image of the bullet entry into the headrest, the shot had to be quite close because of the visible soot and powder impacts (“stippling”). Further confirmation came with the trajectory determination that indicated the shot had to have originated within the truck cab, not outside.

“Paraffin” Test

The reaction of diphenyl amine with nitrate-containing compounds to produce a blue color was developed into a test for the presence of gunpowder on the hands of suspected shooters years ago. The test involved the pouring of melted paraffin over the hands of the individual being tested. The paraffin, once solidified, was then peeled off and subjected to a solution containing diphenyl amine. Any nitrates present reacted by turning deep blue. The test soon fell out of use owing to the many sources of nitrates in the environment that could lead to false positive responses. Modern testing procedures using adhesive-faced aluminum disks and CCSEM–XRF have already been described.

Newly introduced techniques that appear to be based on the old diphenyl amine reaction are hitting the market. The same old arguments that put the paraffin test out to pasture must again be raised with the newest version. An additional concern is the possibility that subsequent testing by CCSEM–XRF might be precluded by the test. Although claims have been made to the contrary, this has yet to be substantiated by a reliable source with no vested interest. The best policy is, without a doubt, to stick to proven, scientifically reliable testing and stay away from forensic equivalents of snake oil.

Determination of Time since Discharge

A longtime goal of shooting incident investigators has been to come up with a scientifically valid method for estimating the time since discharge of weapons, cartridge cases, and shot shells. That is, a means of scientifically verifying the proverbial smoking gun.

Obviously, the ability to determine whether discharge was recent could significantly assist in the reconstruction of a shooting incident.

Andrasko and Stahling of the Swedish National Laboratory of Forensic Science, in a paper published in the *Journal of the American Academy of Forensic Sciences* (volume 44, number 3, 1999), presented a method for estimation of time since discharge of fired cartridge cases. The method is based on sampling the atmosphere inside cartridge cases and analyzing the samples for the presence of naphthalene or an unidentified compound designated TEA2 compound. This paper followed a 1998 paper (volume 43, number 5 of the same journal) concerning a study of shotguns for time since discharge using the same technique.

The results of the studies indicate that it is possible to analyze the atmosphere within shotgun barrels and within cartridge cases and shot shells and estimate the time since discharge. The studies indicated that naphthalene and TEA2 compound persist for only a few weeks. Thus, positive results indicate that discharge occurred within several weeks as opposed to several months. Cartridge cases and shot shells left exposed to the elements were found to lose the components of interest much more rapidly than otherwise.

The analytical procedure is not being widely used outside of Sweden and has not been verified or generally accepted by the U.S. forensic community at this juncture. It does, however, appear to offer promise as a means for establishing some useful information in shooting incidents in some instances.

Case Study

A man was found on the floor of his living room dead of a gunshot wound to the right temple area. A handgun was lying on the floor nearby. Investigators found no signs of forced entry, no ransacking, or evidence of a struggle. The initial conclusion was that it was a suicide. Figure 11.21 shows the entry wound as visible at the scene. After the body was taken to the morgue and cleaned up, some evidence of importance was revealed beneath the blood as seen in Figure 11.22. Although the stippling around the entry wound was

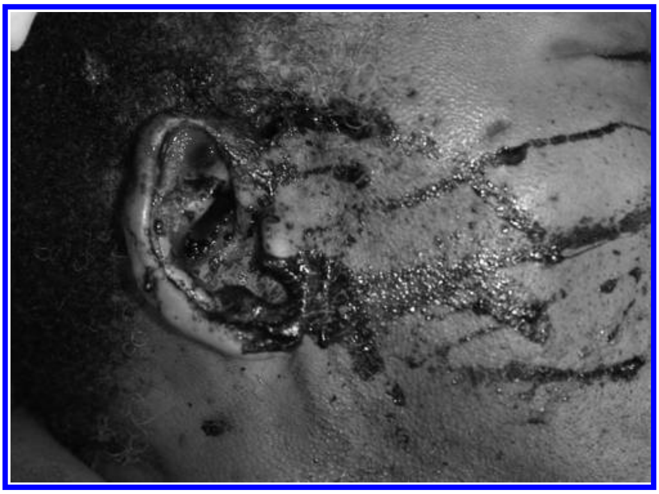

Figure 11.21 Victim at scene.

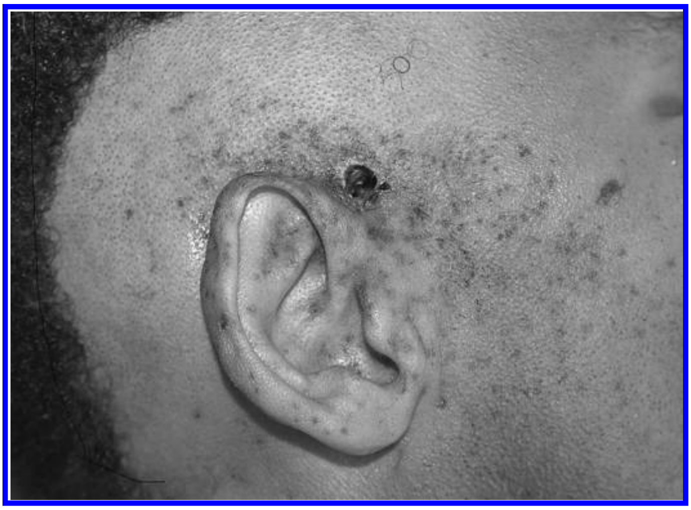

Figure 11.22 Victim at morgue after clean-up.

troubling in light of the initial finding of suicide, it was not completely out of reason. It would be unusual for someone to shoot themselves from a distance of at least 12 inches away, but certainly not unheard of. However, the real deal breaker came when the pathologist checked the hand of the deceased and found stippling on the back of the right hand. There simply was no way he could have shot himself in the right temple, holding the gun barrel approximately 12 inches away, and having his right hand positioned in a way that stippling would be produced as seen in Figure 11.23.

Or was there a way? Clearly a reenactment was called for. It was quickly determined that by placing the right hand up by the face and using the left hand and thumb, it would be possible to do. However, such an awkward position, although possible, is highly improbable (Figure 11.24). Accordingly, the case was investigated as a homicide, a suspect developed, and a conviction ultimately achieved.

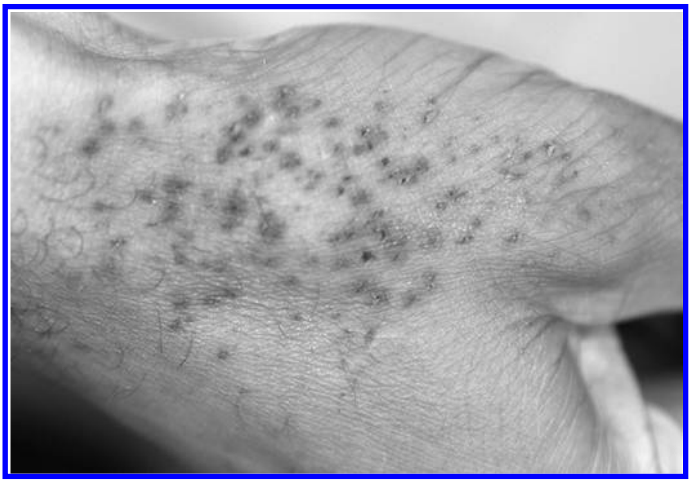

Figure 11.23 Stippling on the back of the victim's right hand.

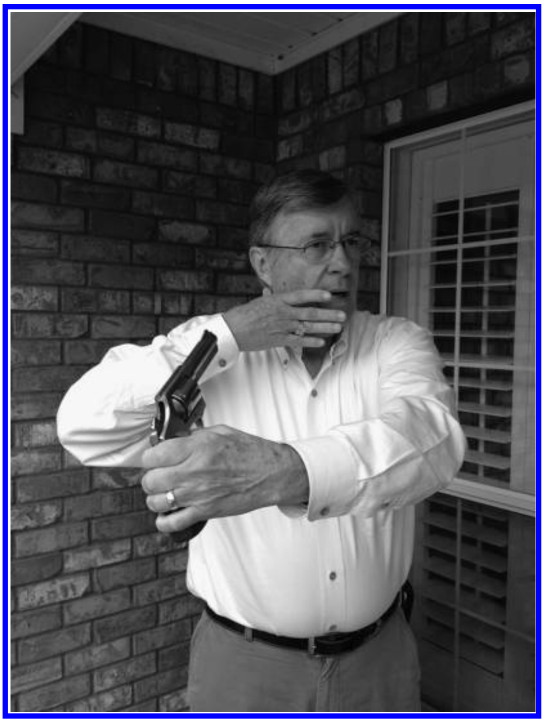

Figure 11.24 Possible shot orientation (but improbable).

Exercises

1. Which one of the following is *not* a component of GSR?
    a. Gunpowder
    b. Soot
    c. Vaporous lead
    d. Nitric acid
2. Which substrate is *least* suited to preparing test firings for stippling?
    a. Glass
    b. Plastic sheet
    c. Foam board or Kraft paper
    d. Wood
3. What produces stippling?
    a. Partially burned gunpowder
    b. Unburned gunpowder
    c. Lead vapor
    d. a and b are correct
4. What is the method to use for lifting GSR off a vehicle windshield?
    a. Gel lifting
    b. Adhesive lifting
    c. Transfer to moistened piece of chemical filter paper
    d. Tape lifting

5. What should be done to preserve GSR lifts for lab submission?
   a. Place in sheet protector
   b. Air dry and place face up in a shallow box
   c. Photograph
   d. a and b are correct
6. What should be done with bloody garments having bullet holes in them?
   a. Discard them
   b. Cut out the area of the hole and submit for testing
   c. Air dry and package in paper
   d. Place in an airtight plastic container
7. How do crime scene investigators best locate GSR?
   a. Using a magnifying glass
   b. Visually
   c. With a magnet
   d. Using a tape lifter
8. Which of the following travels the farthest, all having the same initial velocity?
   a. Particulate lead
   b. Gunpowder particles
   c. Soot
   d. a and b are correct
9. What forces act on gunpowder particles in flight?
   a. Gravity
   b. Air friction
   c. Surface tension
   d. a and b are correct
10. How are muzzle-to-target distances expressed?
    a. As a range
    b. As an approximation
    c. As an exact distance
    d. Plus or minus a few feet
11. How should articles of clothing suspected of having GSR present be packaged?
    a. Separately and in paper
    b. Together in paper
    c. Together in plastic
    d. Separately in plastic
12. What type of gunpowder would travel the farthest, given the same initial velocity?
    a. Spherical or ball
    b. Flattened ball
    c. Flake
    d. Tubular
13. What is the general rule for finding a pattern of GSR?
    a. Within arms length
    b. Less than 12 inches
    c. Less than 6 inches
    d. Less than 3 inches

14. Individual particles of ball powder might be found as far as ______ away?
    a. 20 feet
    b. 6 feet
    c. 1 feet
    d. 3 feet
15. What is the value of photographs of stippling patterns on bodies?
    a. Useless for comparison purposes
    b. Very valuable for testing/comparison purposes
    c. More important for illustration purposes than anything
    d. Shows what type of powder was used

Answers: (1) d, (2) a, (3) d, (4) c, (5) d, (6) c, (7) a, (8) a, (9) d, (10) a, (11) a, (12) a, (13) a, (14) a, (15) b

Suggested Readings

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Bullet Hole and Wound Characteristics

12

The careful examination of bullet holes at shooting scenes is essential to maximizing the information that may be derived at a shooting scene. This means not only looking closely with the unaided eye, but also examining with a hand lens.

A closer inspection of Figure 12.1, for example, reveals numerous dark specks on the surface surrounding the bullet hole in the sheet metal as well as some discoloration. That material is actually gunshot residue (GSR) that could be easily overlooked if a hand lens was not used to inspect the surface. Another consideration is whether or not a hole is actually from a bullet. The investigator at the scene needs to have a test kit available for detecting lead and copper, as shown in Figure 12.2.

For bullet wounds in bodies, the shooting reconstructionist must rely on the forensic pathologist for wound evaluation and the location of trace evidence such as gunshot residue (see Table 12.1). Many times there will be bullet holes in overlying clothing that penetrate the underlying tissue necessitating examination by the crime laboratory as well as the pathologist.

Bullet Holes in Clothing and Underlying Tissue

It is important for the scene investigator to have an understanding of bullet holes in inanimate objects, and how their appearance is affected by changes in muzzle-to-target distance and changes in ammunition. This allows the investigator to recognize certain characteristics associated with, for example, close-range shots as opposed to distance shots. This information can be vital to knowing how to go about assessing the scene for other evidence of shooter position. Likewise, it is important to be able to recognize the general characteristics of bullet wounds as related to distance of shot.

For purposes of our discussion, we will follow the conventions recognized and used by many forensic pathologists when describing muzzle-to-target distance. The distances of contact/near contact, intermediate, and distant will comprise the range of shot delineations that we will discuss. We will not try to distinguish between hard contact and loose or soft contact. The term contact/near contact will designate that the muzzle is either touching the target or is just slightly above it.

Some bullet entry/exit basics are in order before we proceed any further with our discussion of bullet hole and bullet wound characteristics.

- Bullets penetrating targets at approximately 90° tend to produce circular entry holes/wounds.
- Bullets penetrating targets at less than 90° tend to produce oval entry holes/wounds.
- The smaller the angle of impact, the longer the oval entry hole/wound.

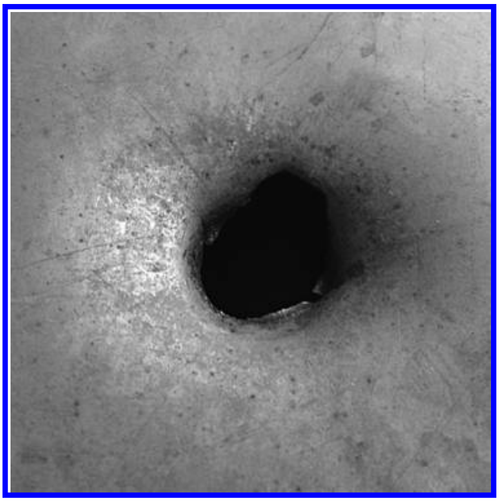


Figure 12.1 Bullet hole in sheet metal.

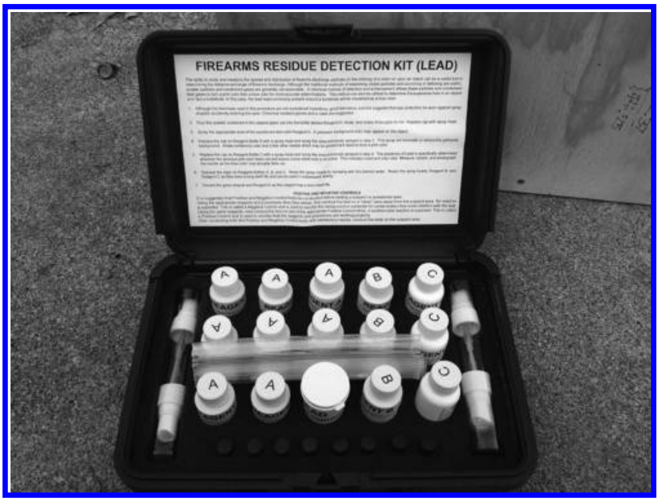


Figure 12.2 Lead and copper detection kit.

Table 12.1 Wound Characteristics

Contact/Near Contact	Intermediate Range	Distant Range
• Stellate tearing	• Powder stippling	• Abrasion ring
• Soot deposits in/around wound	• Possible soot	• Bullet wipe
• Charring	• Abrasion ring	
• Powder in wound	• Bullet wipe	
• Abrasion ring		
• Bullet wipe		
• Muzzle imprint		

- Bullets striking intermediary targets tend to produce irregular entry holes/wounds in secondary targets because of destabilization (yawing).
- Bullet holes in elastic media, including human tissue, tend to be smaller in diameter than the bullets that produced them.
- Bullet entry holes/wounds can often be distinguished from exit holes/wounds by the visible presence of bullet wipe and/or abrasion rings or collars.
- The size of a bullet entry relative to an exit does not always fit the "small entry, large exit" theory, but depends on the target type and bullet design.

When a weapon is discharged, rapidly expanding gases erupt from the muzzle. These gases are extremely hot as a result of the combustion of the powder charge. The combination of the heat and the expanding gases can cause damage to anything in close proximity. With regard to articles of clothing, differences will be noted depending on whether the fabric is made of natural fibers, such as cotton, or synthetic fibers, such as nylon. Additionally, the fabric weave can produce varying effects. The particular weapon/ammunition combination used introduces additional variables and, in the case of contact shots, how tightly the muzzle was held against the surface.

In Figure 12.3, a .22 caliber handgun was fired at contact distance using Winchester .22 long rifle ammunition. The shots were fired into cotton twill, a fabric with a relatively tight weave. Figure 12.4 also shows a contact shot with a .22 LR but through polyester cloth. Figures 12.5 and 12.6 show the result of contact shots into cotton twill and polyester material but with a 9-mm handgun. There is a common element for the shots fired into the polyester cloth: both the .22 caliber and the 9-mm bullets show relatively large holes at the points of impact. This is attributable to the muzzle blast literally vaporizing the polyester fibers. The cotton cloth gives the classic stellate tearing with some singeing only.

The characteristics for shots into fabric are summarized in Tables 12.2 through 12.4.

These characteristics vary somewhat depending on the ammunition and the fabric as already pointed out. For example, sometimes there will be little or no soot deposits, and other times—owing to "dirtier" loads—soot deposits will be quite evident. Likewise, tearing may or may not occur depending on fabric weave and the particular load being fired.

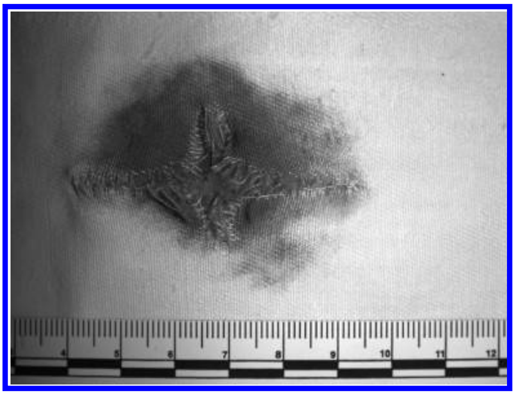


Figure 12.3 Contact shot into cotton cloth (.22 LR).

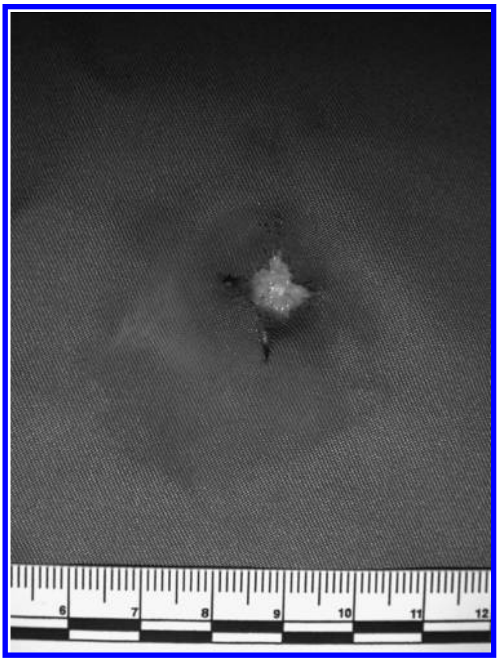


Figure 12.4 Contact shot into polyester cloth (.22 LR).

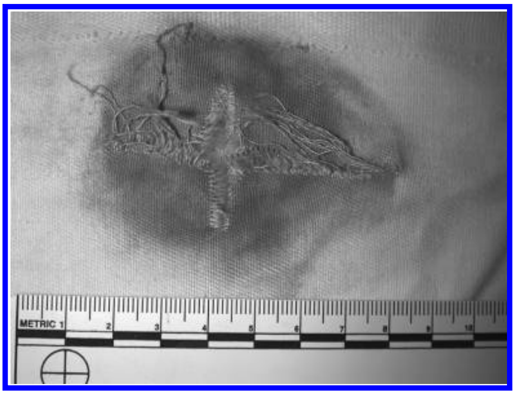


Figure 12.5 Contact shot into cotton cloth (9-mm).

Normally, a hand lens or magnifier will be required in order to be able to see the singeing or melting of the fibers around the margins of the fabric. Sometimes, however, it is possible to see these effects with the unaided eye. If conditions permit, it is possible to feel the melted ends of synthetic fabrics for the characteristic globular nodes present.

Table 12.3 summarizes the possible indicators of an intermediate range shot. The term "intermediate" can sometimes be misunderstood by persons not familiar with the term. Intermediate range is simply defined as the range at which that weapon and ammunition combination will deposit visible powder particles on a given target. Once again, "intermediate range" is a function of fabric type and ammunition type (caliber/gauge and powder type and quantity). Change one variable, and different results may be produced. The bottom line is simply if visible gunpowder particles are observed around

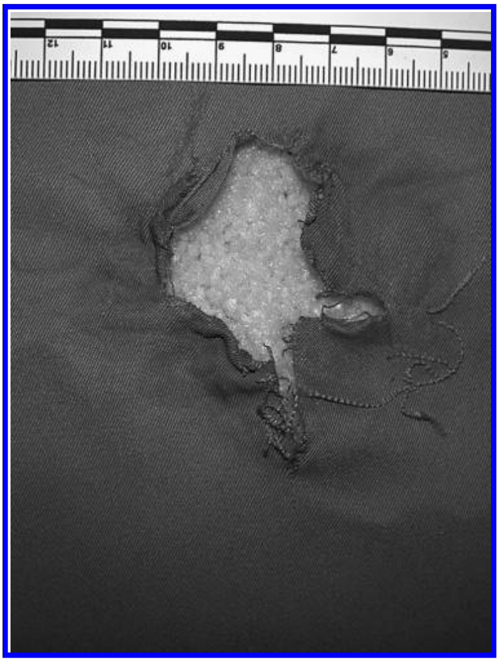


Figure 12.6 Contact shot into polyester cloth (9-mm).

Table 12.2 Characteristics of Contact/Near-Contact Shots into Fabrics

Natural Fibers (Cotton, Wool, Silk, etc.)	Synthetic Fibers (Nylon, Polyester, etc.)
• Stellate or irregular tearing • Burning or singeing • Possible soot deposits (especially for loose contact and near contact)	• Stellate or irregular tearing • Melting • Possible soot deposits (especially for loose contact and near contact)

Table 12.3 Characteristics of Intermediate Range Shots into Fabrics

Natural Fibers (Cotton, Wool, Silk, etc.)	Synthetic Fibers (Nylon, Polyester, etc.)
• Visible powder particles • Possible soot deposits (depending on distance) • Bullet wipe	• Visible powder particles • Possible soot deposits (depending on distance) • Bullet wipe

Table 12.4 Characteristics of Distant Shots into Fabrics

Natural Fibers (Cotton, Wool, Silk, etc.)	Synthetic Fibers (Nylon, Polyester, etc.)
• Bullet wipe	• Bullet wipe

the margins of a bullet hole in fabric, the muzzle-to-target distance is defined as being of intermediate range.

Distant shots into fabric do not result in any of the characteristics seen in contact/near-contact shots or intermediate range shots except for bullet wipe. Bullet wipe is the grease and soot deposits that are transferred from the surface of the bullet to the margins of the material (fabric, wood, skin, etc.) the bullet passes through. In effect, the target material wipes the bullet clean as it passes through. Bullet wipe may not always appear or it may be present but difficult to visualize owing to the presence of blood and/or it being on dark clothing or material. The characteristics of distant shots into fabric are summarized in Figure 12.4.

With regard to human tissue, the characteristics of contact/near-contact shots are equally recognizable as compared to fabric as shown in Table 12.1. Of particular note will be the possible presence of an abrasion ring surrounding the entry wound when tearing of the tissue has not taken place. The abrasion ring is the result of the skin stretching and then being abraded by the bullet as it passes through. It should be noted, however, that the abrasion ring may be absent for high-velocity rifle and handgun bullet entry wounds. This is also the case for entry wounds to the palms of the hands and soles of the feet for any type round.

As with fabric, bullet wipe is also a possibility. These characteristics are summarized in Table 12.1 also. It should also be noted that a contact/near-contact shot can produce a muzzle imprint, particularly when there is underlying bone present such as in a head shot. Muzzle imprints are abrasions resulting from the gases from discharge causing the skin to expand out against the muzzle of the weapon. An example of a muzzle imprint from a 12-gauge shotgun is shown in Figure 12.7. The weapon was an over/under double barrel shotgun. The muzzle imprint of the upper, unfired barrel is clearly visible to the right of the entry wound produced by the lower barrel.

It is particularly important for the investigator to be able to recognize the presence of an abrasion ring or collar around the margins of a bullet wound as this is a clear indication of an entry wound rather than an exit. One possible area of confusion can result when there is a shored exit wound. A shored exit wound is the result of the area of the body at which the bullet exits having been supported or tightly bound by clothing, a vest, or other article. The shored exit wound (Figure 12.8) can sometimes be recognizable by an associated fabric impression. Naturally, any question concerning the origin of an abrasion ring around the margins of a bullet wound should be referred to a forensic pathologist.

When the weapon is fired from any distance such that gunpowder particles can impact the skin around the entry wound, such impacts will typically be manifested by what is generally referred to as powder stippling. Partially burned and unburned gunpowder particles are expelled from the muzzle upon discharge along with soot. If the muzzle is close enough to the victim, the presence of both soot and stippling is likely. As the muzzle of the weapon is moved farther away from the intended target, a distance will eventually be reached at

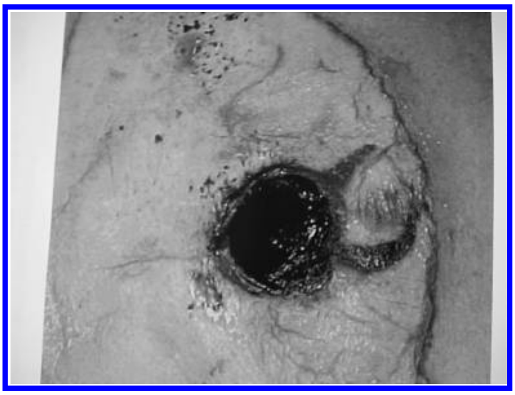


Figure 12.7 Muzzle imprint (shotgun).

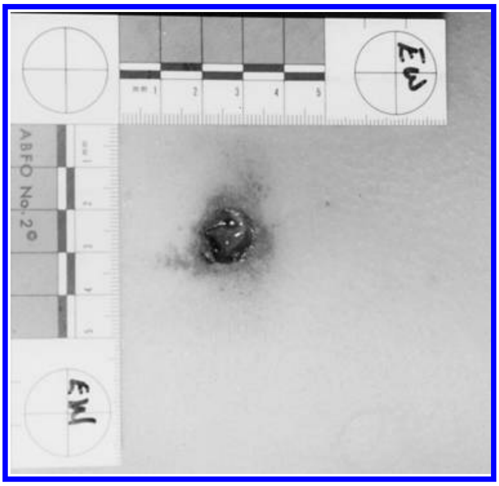


Figure 12.8 Shored exit wound (back-pressed against seat back when shot).

which the soot does not reach the target. Gunpowder particles, by virtue of their greater mass, are able to travel greater horizontal distances than soot particles. Thus, powder stippling effects will still be produced after the soot deposition ceases with increased muzzle-to-target distance.

Powder stippling is manifested by small, dark spots around the margins of the wound. These spots can represent bruises or abrasion from the impact of the gunpowder particles with the skin. The potentially injurious nature of gunpowder particles to human skin is evidenced by close-range shots into painted metal surfaces, such as car doors, and the subsequent chipping of the paint around the bullet hole as a result of the powder impact. Powder particles can even imbed themselves into the skin to produce a powder "tattoo." An example of powder stippling is shown in Figure 12.9.

As already stated, the particular round and weapon involved will have a significant effect on the distances at which soot and powder will travel. As a general rule of thumb, we typically do not see soot deposition beyond about 24 inches. As for powder deposition, the general rule of thumb is that we do not expect to see it beyond "arm's length." As with any rule of thumb, these statements are offered for general investigative purposes only, and are not intended to represent hard and fast facts. Obviously, there is a huge difference in soot/powder deposition for a .22 short cartridge as compared to a .45 ACP cartridge, for example. It is only through actual test firing with the weapon and ammunition like those used in the shooting that one can establish approximate muzzle-to-target distances to any reasonable certainty.

It is important for the investigator to be fully aware of possible reasons why some of the characteristics of bullet holes in inanimate objects, as well as in human tissue, may not conform to their expected or predicted appearance. This is especially of concern when little or no gunpowder particles (inanimate objects) or stippling (human skin) are found. The possible conclusions that arise when little or no gunpowder/stippling is present are as follows:

1. The muzzle-to-target distance was too great to produce more of a pattern.
2. The shot was close enough for the powder to strike the surface, but something prevented the gunpowder from reaching it or removed it after it impacted (e.g., rough handling of clothing taken into evidence).

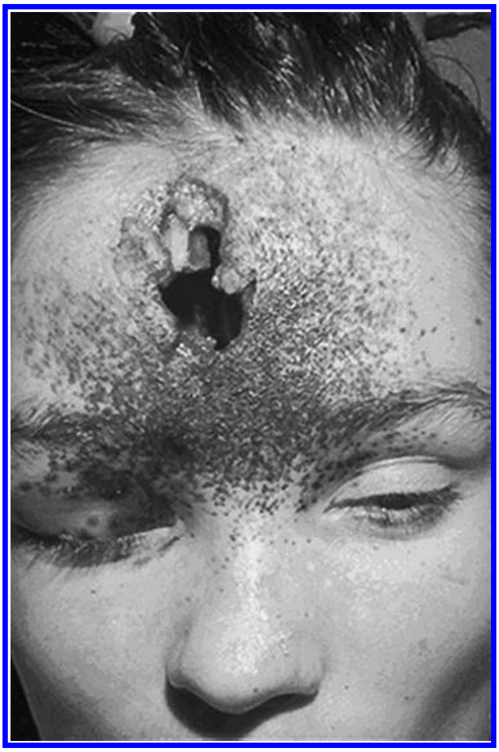


Figure 12.9 Stippling.

As far as preventing the powder from reaching the target is concerned, obviously any intervening target might be capable of that. Thus, when a weapon is fired through a pillow and into a victim, most or all of the powder would be stopped while the bullet could still pass through. Other common intermediary targets likely to be encountered at shooting scenes would include hair, articles of clothing, glass windows, wooden doors, walls, and curtains.

Another possible reason why powder particles might not show up on examination at the crime laboratory or at autopsy is attributable to handling. Because the top priority at any shooting scene is to administer aid to the injured, the clothing is frequently ripped or cut apart and stripped off by paramedics during life-saving efforts. This process can and does alter the amount of gunpowder that may have initially been present. This can be a particular problem when the powder is only loosely held on the surface of a garment owing to the distance of the shot and/or the type of fabric (smooth, tight weave vs. loose, bulky).

In the case of powder stippling in human skin, the mechanisms by which it is produced make it unlikely that just wiping or washing the surface of the skin could obliterate it. In other words, one would not expect simple mechanical action in the form of wiping or washing to remove evidence of burning or bruising, to say nothing about the improbability of removing powder imbedded in the skin. The presence of overlying hair can prevent the production of stippling, even at close range. For this reason, it would be important to collect hair covering a wound and submit it to the crime laboratory for examination. Many times, close-range shots through overlying masses of hair will exhibit burning/singeing as with any natural fiber.

Reconciling Bullet Holes in Clothing with Underlying Wounds

Quite often information as to the position of the victim's gunshot wounds at the time shots were fired can be ascertained by examining and comparing the locations and characteristics of bullet holes in clothing and underlying wounds. It is unfortunate, that in some jurisdictions, the determination of muzzle-to-target distance is based solely on the pathologist's findings without regard to the fact that the wound was covered by an article of clothing. It would seem apparent that the outermost layer would be the most logical thing to examine and test for purposes of establishing approximate muzzle-to-target distance. Sometimes that is apparently overlooked.

Clearly, it would be possible for an individual to receive a contact shot to his shirt, for example, and yet the wound exhibit the characteristics of an intermediate-range shot in the form of powder stippling. This could merely result from wearing a loose-fitting garment and having it hang away from the body at the time the shot was fired. Although this may not necessarily represent a fatal flaw in the reconstruction of a shooting, it certainly represents less than a thorough examination of all the available evidence.

Proper protocol requires the examination and testing of both sides of all overlying garments that bullets have passed through as well as having a forensic pathologist conduct an autopsy and examine the bullet wounds. Under the ideal scenario, findings of the crime laboratory and the autopsy findings will be reviewed before arriving in court only to learn that there is disagreement.

The review and reconstruction of a shooting incident should encompass cross-communication between those involved to ensure that the following issue are addressed:

- The autopsy report and the criminalistics report should be in concert.
- The criminalist should, at the least, read the autopsy report before issuing a criminalistics report.
- The pathologist and the criminalist should be in communication with one another on cases of mutual concern.
- Someone should be charged with comparing related findings in cases before reports are issued.
- The prosecutors should assemble their witnesses together for a pretrial conference in order to discuss their planned testimony.
- Both sides of any garment bearing bullet holes need to be examined in the laboratory.
- Although it is more in the realm of wishful thinking, paramedics should report any alterations to garments while at the scene.

THE TRAYVON MARTIN CASE

A classic example of what can happen when the above checks and balances are not followed took place in the Trayvon Martin case during the state's presentation of their case. During testimony provided by the firearm examiner for the state, she stated that she had examined the hoodie worn by Trayvon Martin (Figure 12.10) that had a bullet hole in the chest and had found characteristics consistent with a contact shot (i.e., tearing and no powder particles). She was followed by the pathologist who conducted the autopsy on

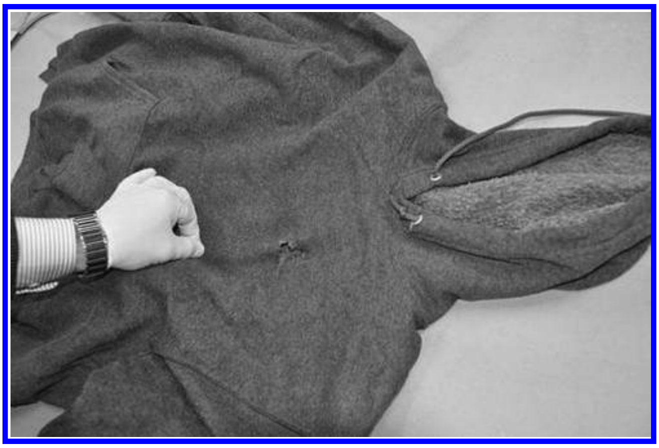


Figure 12.10 Hoodie in Trayvon Martin case.

Trayvon Martin who testified that he found evidence of an intermediate-range shot (powder stippling around the entry wound).

Clearly, the testimonies of the firearm examiner and the pathologist concerning the shot fired to the chest of Trayvon Martin were in conflict. As it turned out, however, it was the evidence that the defense needed to show that Trayvon Martin was on top of George Zimmerman when the shot was fired. This was because the evidence clearly indicated that while the gun barrel had to be in contact with the hoodie, it was not pressed against the chest of Trayvon Martin, but was far enough away to produce stippling on the skin around the entry wound. As the defense expert testified, that required Trayvon Martin to be on top of George Zimmerman and leaning forward exactly as Mr. Zimmerman had testified to.

In some instances, it may be necessary to use a mannequin to assist in determining the relationship of bullet holes in clothing to wound locations. Consideration must be given to the stature of the individual involved in setting up such an experiment. When the available mannequin pretty closely approximates the stature of the shooting victim, things are admittedly simplified. If not, appropriate compensations need to be made. In what can clearly be the worst-case scenario, someone of similar stature may be cajoled into donning some disposable coveralls, face mask, gloves, and booties, and then putting on the victim's outer garments. This is sometimes asking a bit much when the clothing is heavily coated with dried blood and/or tissue. In such cases, the potential health risks may be deemed too excessive.

Figure 12.11 shows a mannequin dressed in the shooting victim's clothing and lying on a couch similar to the one at the scene. In this case, the mannequin was a good fit for the shooting victim in terms of stature. As it turned out, there were two possible scenarios that fit the evidence, one consistent with the defendant's statements and one in conflict. Both scenarios were equally plausible as to how the shooting occurred. Accordingly, a plea bargain was reached. Figures 12.11 through 12.13 illustrate the use of a mannequin.

Another good example of how reconciliation of bullet holes in clothing with wounds in underlying tissue can be useful in shooting reconstructions is found in the presence of graze wounds. When folds of fabric are passed through, a series of in/out holes result.

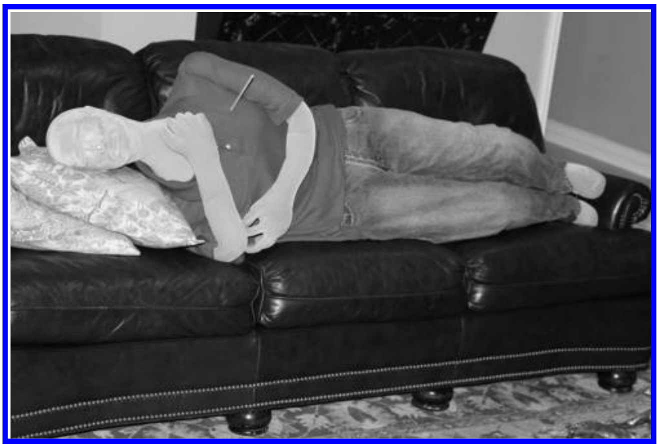


Figure 12.11 Mannequin in position the victim was found.

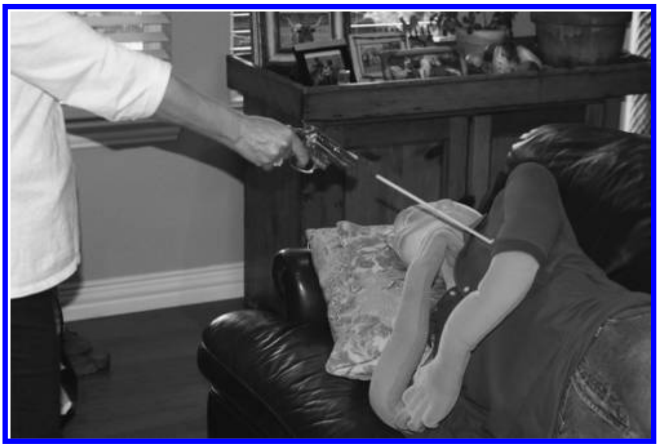


Figure 12.12 Scenario #1.

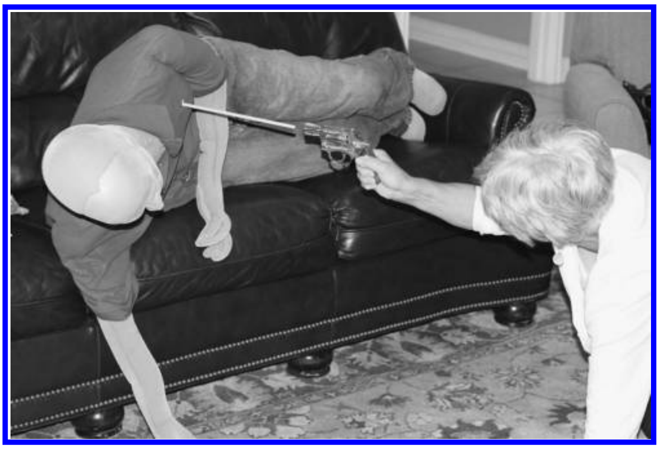


Figure 12.13 Scenario #2.

When the pathologist reports a graze-type injury, this information may be of value by itself, but the combination of the wound appearance with the bullet hole description in the clothing can provide strong evidence as to the likely victim position at the time of bullet impact. Figure 12.14 is a representation of the folds created that typically result in trousers when the leg is bent. It would be doubtful that an in/out/in/out/in/out type pattern would result in any other manner (Figure 12.15).

In summary, wounds should be reconciled with bullet holes in clothing as part of the shooting reconstruction effort whenever appropriate. Questions regarding bullet paths

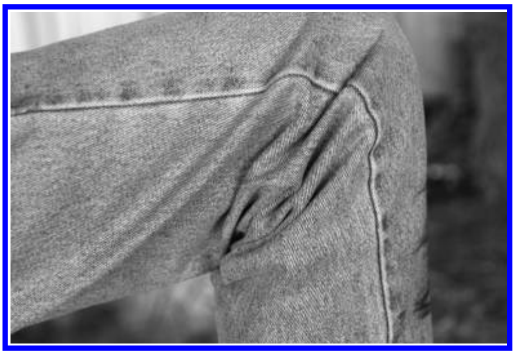


Figure 12.14 Folds in jeans, leg bent.

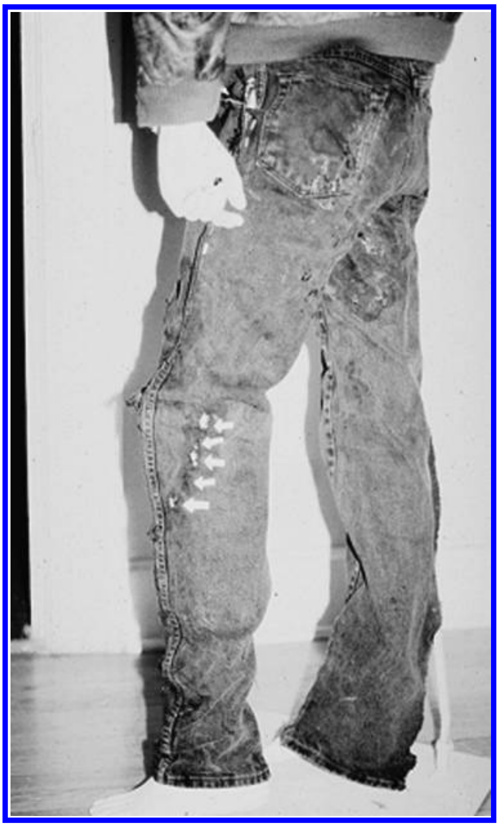


Figure 12.15 In–out–in–out series of bullet holes in outer left leg of jeans.

and directions should be resolvable through comparison of the laboratory findings with the pathological findings. Any questions that arise can often be answered through using the victim's clothing placed on a mannequin or an individual of comparable stature.

Bullet Holes in Glass and Glass Injuries

When bullets pass through glass, it is important to be able to determine the directionality of the shot. For example, in a shooting involving a vehicle, was the bullet fired from inside the car out or from outside in? In most cases, the answer is fairly easy to ascertain. Other situations can present obstacles to this determination that range from difficult to insurmountable.

Before proceeding with a discussion of bullet hole characteristics in glass, a brief description of glass manufacture and the types of glass commonly encountered in shooting incidents is in order. Glass is described chemically as a supercooled liquid. Glass manufacture in the United States can be traced back to the Jamestown colony in Virginia. Sand, lime, and potash were heated to the melting point to produce a molten soda–lime glass that skilled glassblowers formed into all sorts of containers and objects. This can still be observed by tourists visiting the restored Jamestown Village.

Modern glass is made using several different processes including rollers that the molten glass is formed with and a float process involving molten tin that the molten glass floats across. The tin float process offers an inexpensive route to quality glass. In this process, tin particles are fused to the "down side" of the glass. This provides a means for ascertaining shot direction as will be discussed later in this section.

Vehicles use safety plate glass for windshields. Safety plate glass, also used in large storefront windows, usually consists of two sheets of plate glass with a piece of clear plastic in between. The plastic is cemented to the glass sheets to form a laminate. The end result is that if an object, such as a bullet, passes through the glass, the glass essentially holds together even when fractured, thanks to the plastic sheet.

All other glass found in a U.S.-manufactured vehicle is tempered glass (sides and rear window). European vehicles typically have tempered glass entirely. Tempered glass is much stronger than ordinary plate glass. Tempered glass consists of a single sheet that has had stress induced during the manufacture through heat treating. Because of the stress induced during heat treatment, tempered glass crazes or fractures into tiny, rectangular fragments upon impact that pose little threat of injury. Tempered glass is also found in some shower enclosures and shower doors, as well as in windows and other glass panels used in buildings and residences. There will be no problem determining that tempered glass was present if a bullet passes through, thanks to the crazing that results.

Plate glass, as used in ordinary business and residence windows, consists of a single sheet of nontempered glass. Plate glass is sometimes reinforced with an internal wire mesh in commercial windows. When plate glass breaks, dangerous "spears" of glass are produced.

When a force impacts a sheet of glass of any type, bending, stretching, and, ultimately, breaking takes place. This is manifested by fracture lines that radiate out from the point of impact like spokes on a wheel. With windshield glass, these radial fractures first occur on the sheet of glass on the side opposite to the one being impacted. Ultimately, both sheets will exhibit radial fractures, but they will usually not coincide. Also present will be a series of concentric fractures that form next as the glass bends in the direction of the force. These are initially formed on the same side of glass that the force impacts. As the bending of the glass continues, both sheets of glass become involved. The number of concentric fractures is related to the type of glass, the size of the window, and the rigidity of the window in the frame. Concentric fractures may be minimal or completely absent in some cases. Concentric fractures, combined with the radial fractures, give the appearance of a spider web. This can be seen in Figure 12.16.

Radial fractures from adjacent bullet holes can reveal shot sequence because radial fractures in the same sheet will never cross. When a radial fracture terminates into another radial fracture, the terminating radial fracture emanates from a shot that followed the one with the nonterminating fracture. Look closely at Figure 12.17 and see if you can determine

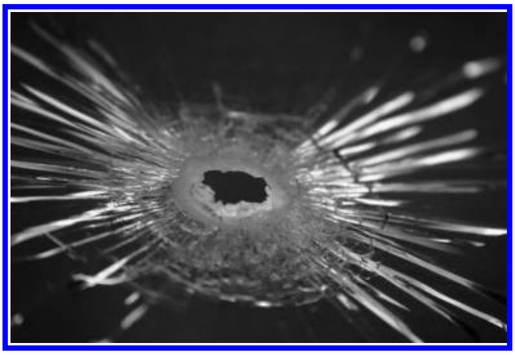


Figure 12.16 Exit side of bullet hole in windshield glass.

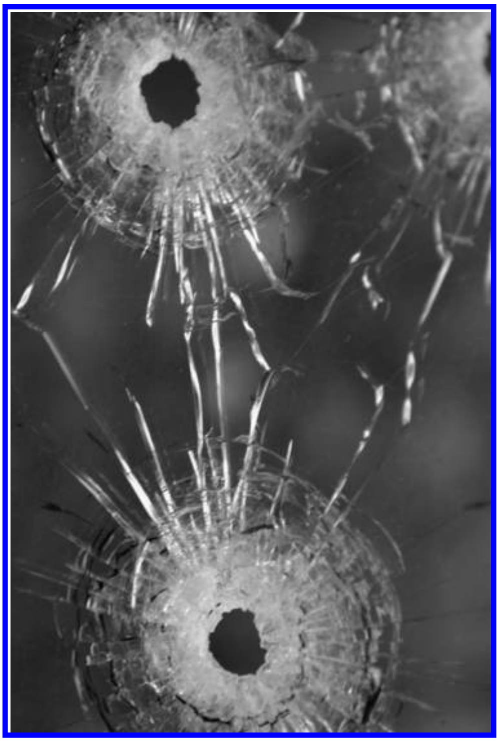


Figure 12.17 Shot order in glass.

which came first. The lower shot appears to have preceded the shot to the left. A word of caution is in order based on reports indicating that this technique of radial fracture termination point determination and shot order may be unreliable. Several of the author's colleagues state that erroneous results can come from this method owing to post-shooting vehicle loading and transport. Numerous attempts to confirm that have been made by the author following test shooting of windshields in vehicles without success, but a word to the wise is nonetheless given.

The same effects are exhibited by tempered glass and ordinary plate glass. With tempered glass, however, the crazing reduces the degree of concentric fracturing and increases the degree of radial fracturing but in a wavy pattern. This is clearly visible in Figure 12.18. Also, only the first shot through tempered glass results in radial and concentric fractures. Subsequent shots are only knocking out portions of the remaining crazed glass. This is also seen in Figure 12.18. A large portion of the glass, if not all of it, gets blown out. However, it is often still possible to discern radial fractures from the first shot if enough glass remains. After-market window tint film, if present, will often hold the crazed glass in place barring some additional force of impact.

When moving vehicles are involved, the location of tempered glass fragments in the road can be deceiving. The location may not coincide with the point at which shots were fired at all. In several cases the author has investigated, shots were known to have been fired from a position considerably uprange from where glass fragments were found. This was simply because the glass held together as the vehicle continued to travel forward until road vibration or a collision caused the glass to fall out.

It is important that glass with bullet perforations be documented as soon as possible. Attempting to move vehicles before documenting the bullet holes in tempered glass will usually result in the glass falling out, even when strips of tape have been placed over the glass. Windshields, on the other hand, are not nearly as fragile.

The determination of direction of force, that is, which direction the bullet was traveling, is possible by noting which side of the glass exhibits a beveled or dished margin at the bullet hole. As when a bullet passes through a human skull, the beveled side will always be on the exit side. This is because as a bullet passes through glass, there is a cone effect of force resulting in more glass being lost on the exit side. For shots at impact angles less than 90°, asymmetrical beveling is produced. These effects are represented in Figures 12.19 and 12.20.

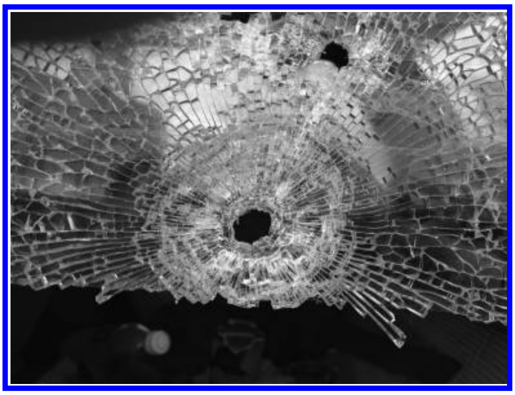


Figure 12.18 Multiple shots to tempered glass (this is the exit side—lower shot was first).

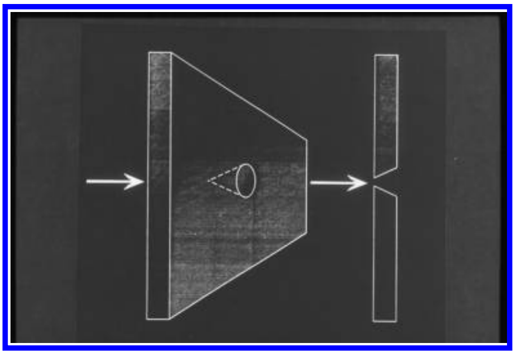


Figure 12.19 Outward beveling.

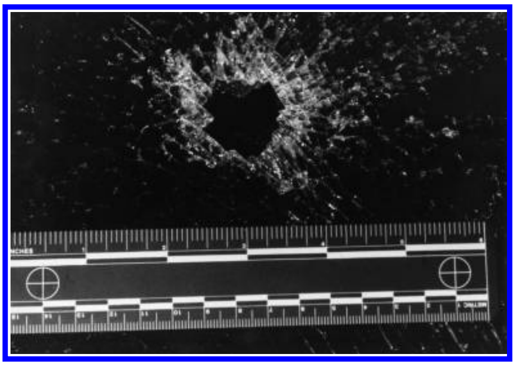


Figure 12.20 Second shot to tempered glass.

Sometimes, especially with tempered glass, this effect is difficult to see or cannot be seen owing to loss of glass. However, most tempered glass is made using the tin float process. This results in the side against the molten tin being impregnated with tin particles. To determine which side was the outside, one only needs a remaining piece from the window frame. By exposing each side of the fragment to ultraviolet light, the side with the tin particles will fluoresce and the other side will not. This means that if fragments from the bullet hole margins can be found on the ground or elsewhere and beveling is discernable, ultraviolet fluorescence can be used to establish shot directionality. In the case of windshield glass, the beveling will usually appear on both sides, but it will be more pronounced and more uniform on the exit side.

If penetration is incomplete, the beveling is on the impact side. This is frequently encountered when BB guns are fired at storefront windows. The tiny, irregular hole produced is indicative of this occurrence. This is referred to as spalling. It is not limited to BB guns, however, and may result from bullet impact wherein a significant loss of velocity has taken place before striking the glass. This is not something that has been frequently encountered in the author's experience.

Another way of ascertaining the direction of force is to examine the concentric and radial fracture edges of a fragment of glass still remaining in the broken plate glass window or windshield. This allows the examiner to denote which side of the fragment is facing out. This may be accomplished by simply marking the outside surface of the fragment “O” with a marker pen before removing it. Additionally, radial fracture edges and concentric fracture edges should also be marked before removal.

With the fragment appropriately marked, the edges are then examined for the presence of conchoidal fracture lines. As it turns out, the conchoidal fracture lines form right angles, the orientation of which depends on whether a radial or a concentric fracture edge is involved. This is illustrated in Figure 12.21. The radial fracture edges tend to show this effect more reliably.

If an intact piece is not available, a piece from the floor or ground may be used if it is possible to determine its orientation in the window. This is often a difficult task. In the case of tempered glass, the tiny fragments do not usually permit this determination. A piece of evidence glass must be properly marked in order for analysis to be possible, as shown in Figure 12.22.

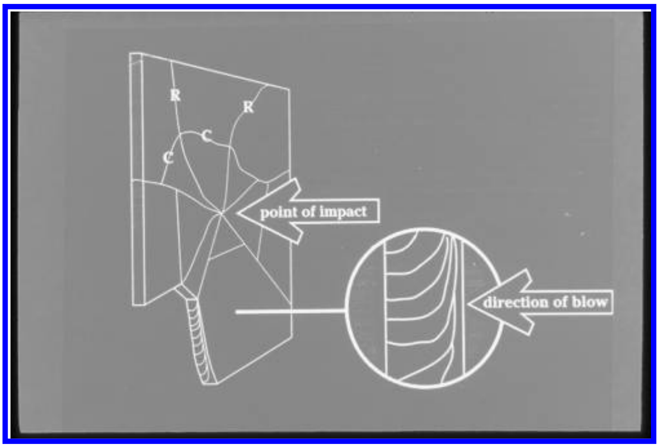


Figure 12.21 Conchoidal fracture lines.

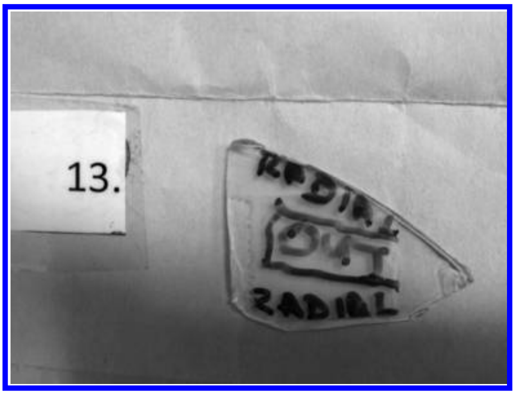


Figure 12.22 Evidence glass properly marked.

The conchoidal fracture lines on the radial and concentric edges are known as Wallner lines (Figure 12.23). The direction of impact may be deduced by knowing which edge one is viewing and following the rhyme: "Ray (as in radial) goes away" and "Con (as in concentric) comes to" as shown in Table 12.5.

It is sometimes important to ascertain exactly where a bullet impacted a glass window. As long as radial fractures are present, all that is required is to find the point of

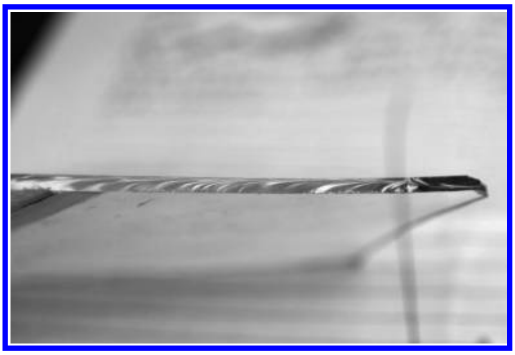
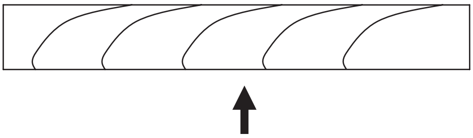
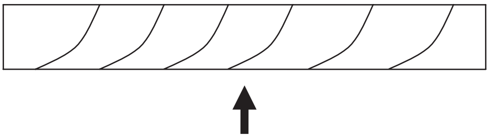


Figure 12.23 Wallner lines.

Table 12.5 Establishing Glass Breakage Force Direction



Direction of force—concentric edge
"Concentric comes to"



Direction of force—radial edge
"Ray goes away"

1. Remove a piece of broken glass still in the window of interest, being careful to note which edges are concentric and which are radial.
2. Also be sure to establish which side is "out" and which is "in."
3. Align the piece perpendicular to your body.
4. View the perpendicular edge with oblique light.
5. Note which direction the fracture lines curve toward.
6. Prepare a table of your results for each bullet hole.

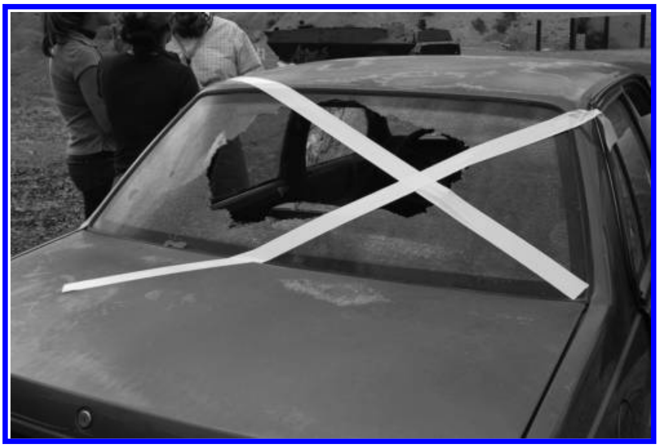


Figure 12.24 Point of impact determination.

intersection of two radial fractures. This is easily accomplished with masking tape. Two strips of tape are run across the window in an alignment with two radial fractures. The point of intersection of the strips of tape is the point of impact. This can then be measured, sketched, and photographed to document. A representation of this technique is shown in Figure 12.24.

Glass injuries occur when an individual is within reasonable proximity to a glass window when a bullet passes through. The glass injuries appear as small, punctate injuries. These can sometimes be mistaken for stippling. Identification of tiny glass fragments within the wounds by the pathologist is essential.

The presence of glass injuries and their location on the body of the victim can assist in the reconstruction of a shooting. Questions as to the position of the arms of the driver in a vehicle shootout, for example, can frequently be answered if bullets have passed through the driver door glass and/or the windshield. This can also be used to establish bullet directionality when bullets pass through glass on both sides of the vehicle and the glass totally falls out. Thus, glass injuries on the left side of the driver's body require bullet entry from the driver side if the driver was seated behind the wheel and facing forward.

In an officer-involved shooting incident, a question as to the justification for the use of lethal force arose. According to the officer's statement, the decedent, who was sitting in the driver seat of a vehicle with the engine running, had his hands "on the steering wheel as he gunned the car toward me." This was the officer's basis for firing the fatal shots that first passed through the windshield and then the driver door glass. At autopsy, examination of the decedent's wounds revealed small, punctate wounds on the inside of the forearm of his right arm and on the outside of his left forearm. This indicated that his arms and hands were up above the driver door window sill and in a position consistent with holding the steering wheel.

Further examination revealed the officer's stated position and the trajectory of the shots were consistent with the glass injuries having occurred with the decedent's hands on the steering wheel. This evidence, along with other physical evidence, resulted in the

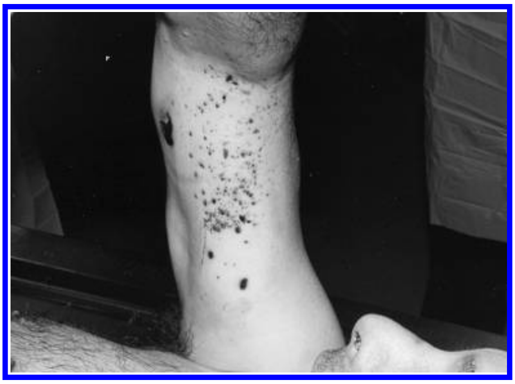


Figure 12.25 Glass injury to inner arm.

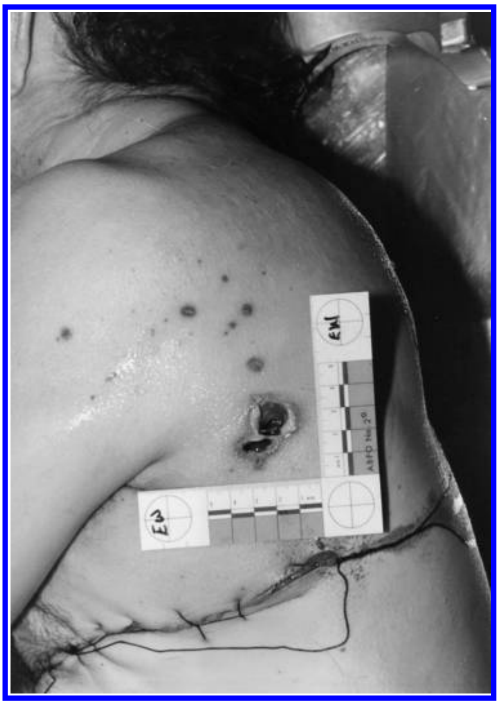


Figure 12.26 Glass injury to left shoulder.

officer being exonerated in the shooting death of the man. Figures 12.25 and 12.26 show the glass injuries that resulted.

Glass lodged in the cavity of hollow point bullets or embedded in the nose of lead bullets can provide information as to which window was impacted. The crime laboratory can conduct analyses of control samples from each window perforated by bullets and compare the physical properties (density, refractive index) and the elemental analyses to the fragments recovered from bullets.

When bullets impact glass of any type, a cloud of pulverized glass is produced. If a person is anywhere in the immediate vicinity, chances are they will be covered by the tiny fragments. Collection of a suspect's clothes and subsequent laboratory examination and analysis of any glass particles found can be used to put an individual at the scene of a shooting where glass was shot through. Even though modern computer-controlled glass manufacturing techniques tend to minimize the analytical distinctions between different batches of glass, these distinctions are still a viable means of identifying which glass splinter came from which window. The high-speed photograph depicted in Figure 12.27 shows the "spray" of glass, both forward and backward, that results from bullet perforations.

Sometimes questions will arise as to whether a vehicle side glass was fully raised before a shootout. Even when most of the glass falls out as a result of a bullet strike, it is often found that the upper window channel will still retain a few fragments of tempered glass. By noting and photographing this, confirmation that the window was up at the start of the shooting can be made.

A word of caution when attempting to reconstruct trajectories through windshield glass where bullets have fragmented is in order (fragmentation is particularly common when semijacketed hollow-point bullets are involved). When bullets pass through slanted windshields, fragment and the fragments strike secondary targets inside the vehicle, such as seat backs, there is often a tendency to use the secondary (into the seat back) impact point of the largest fragment (usually the bullet core) as the second point of reference. Although it is certainly expected that the largest mass will exhibit the closest trajectory to the original bullet, it is quite unpredictable. This means that merely "connecting the dots" (using the primary and secondary impact points to establish trajectory) could result in a proposed shooter position that would not necessarily represent the true position. A .45 ACP Federal Hydra-Shok© bullet that fragmented as a result of striking a side glass (tempered) in a vehicle is shown in Figure 12.28. The deflection resulting from an armor-piercing 7.62 × 39 mm bullet passing through a windshield at an oblique angle is shown in Figure 12.29. The line of fire is represented by the black line. The red line is the apparent trajectory based on the entry hole in the windshield and a secondary impact inside the cab produced by the largest fragment.

When bullets strike slanted windshield glass directly from the front at, say, the midsection, an elongated hole is usually produced because the bullet is striking at whatever angle of inclination the windshield has (assuming a shot fired more or less parallel to the ground). In tests conducted by the author, the width and length of the resultant bullet hole for a particular caliber was somewhat dependent on the bullet design. For example, the percent error for the angle of impact calculation using the hole width/length ratio was 18% for hollow point .40 caliber bullets (Winchester and Federal), but only 3% for blunt nosed soft point (Winchester) in one test.

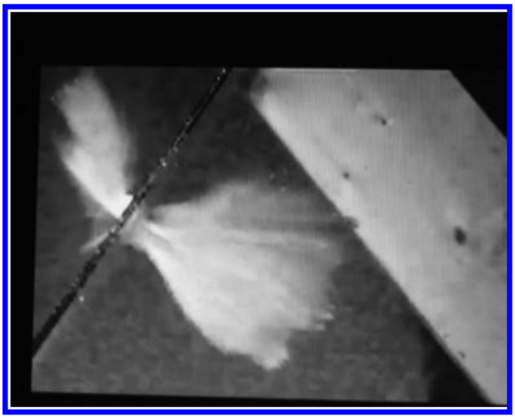


Figure 12.27 High-speed image of bullet passing through glass (left to right).

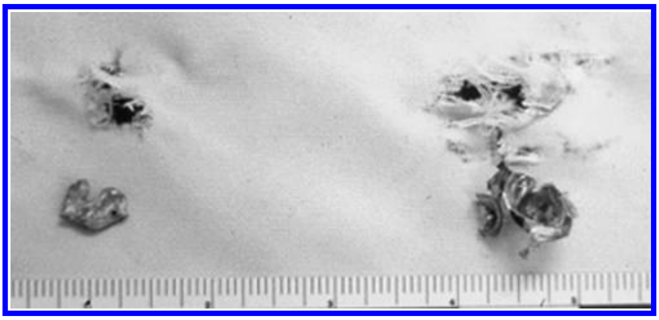


Figure 12.28 Bullet fragmentation upon impact with glass.

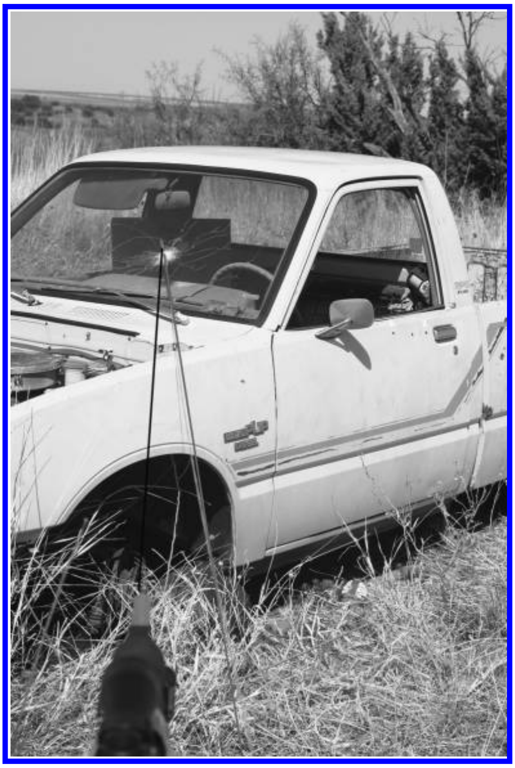
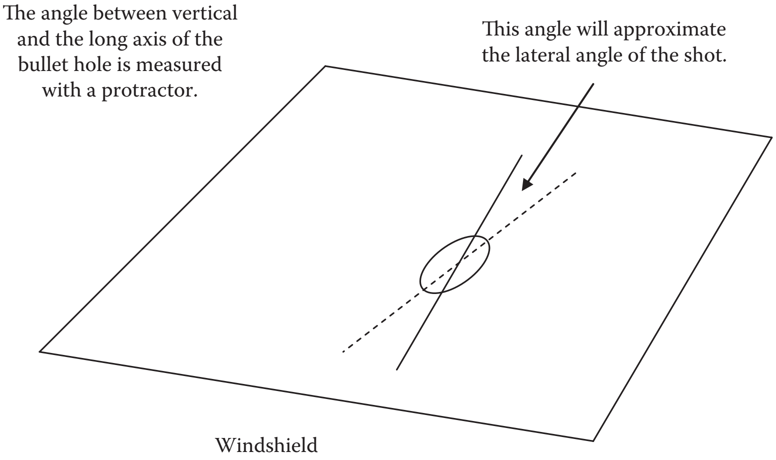


Figure 12.29 Bullet deflection through windshield glass.

This was determined to be the consequence of differences in deformation upon impact and the resultant bullet hole dimensions. Once again, the investigator would be well advised to carry out testing under the particular conditions associated with the shooting incident under study.

As part of the documentation of bullet holes in windshield safety plate glass, the orientation of elongated (oval) bullet holes should be noted. The simplest method is to use a straight edge to bisect the axis of the hole and then use a protractor to measure the degrees of cant of the long axis (as represented by the straight edge) to the left or to the right of vertical. The straight edge is laid down on the glass, and the protractor is then placed on top of it. The base of the protractor is aligned with the plane of the front of the vehicle. Shots fired straight on should show 0° (or very close to zero) of cant from vertical for the long axis. Shots fired at other than directly from the front of the windshield will be recognized by a cant to the left or

Table 12.6 Bullet Hole in Windshield Glass Documentation


The angle between vertical and the long axis of the bullet hole is measured with a protractor.
This angle will approximate the lateral angle of the shot.
Windshield

1. Establish a reference line (solid line above).
2. Establish a bisector for the bullet hole (dashed line above).
3. Measure the angle between the two lines (denoted by the arrow above).
4. Repeat for each bullet hole.
5. Prepare a table of the results for bullet hole.

right of the resultant oval bullet hole. The degree of cant will approximate the lateral angle for the shot. For example, if there is an oval-shaped bullet hole in a windshield and the long axis of the hole has a 30° cant to the right of vertical, the shot was fired from approximately 30° to the left of a vertical through the center of the hole (see Table 12.6).

The vertical angle cannot be reliably determined from the length and width measurements of bullet holes through windshields. This is attributable to bullet deformation/fragmentation and the irregular breakage that takes place in windshield glass. In the one test conducted by the author with .40 caliber Federal rounds, no reproducible results could be obtained and none of the vertical angles of impact calculated from bullet hole width/length ratios were within less than 15° of the actual angle.

When shots are fired through windshields, pass through human targets, and then enter seat backs, one should be very cautious about trying to use the tertiary bullet hole in the seat and the entry hole in the windshield to fix the trajectory. Obviously, bullet deflection can and often does occur under these conditions.

Attempting to determine shooter position from the entry hole in a windshield and a bullet entry wound for an individual inside the vehicle also has some limitations. The position of the victim can be established fairly well if the bullet exits and then penetrates the seat back or other interior component. When this does not take place, the investigator cannot necessarily assume a particular position for the shooting victim. One must always consider the possibility of movement during the shooting, particularly when multiple shots are involved.

In the author's experience, some significant bullet deflection (approximately 6° or more) can result from perforation of a windshield. This is based on numerous test firings using .40 Smith & Wesson rounds with semijacketed hollow points. This is contrary to a report published in the *AFTE Journal* by Gary Rathman several years ago. However, his tests did not include .40 caliber semijacketed hollow points as used in the author's tests. This finding once again underscores the necessity for incident-specific testing.

In summary, the following checklist should be considered and applied as appropriate at each shooting where glass is involved.

Glass Evidence Checklist

1. Determination of directionality of shots
    a. Look for beveling around margins of hole (if the center of the hole is blown out, attempt to locate fragments and reconstruct—use UV light to determine the outside surface). Beveled or dished margin will be the exit side.
    b. Examine radial and concentric fracture edges (plate glass and other nontempered glass only) for the presence of conchoidal fractures—"Ray goes away," "Con comes to." The conchoidal fractures along the edges form right angles away from the direction of force for radial fractures and toward the direction of force for concentric fractures.
2. Determination of shot sequence
    a. Plate glass/windshields—look for multiple intersecting radial fracture lines (when multiple radial fracture lines stop against another, the continuing fractures are usually first).
    b. Tempered glass—the first shot will exhibit radial fractures and possibly concentric fractures as well. Subsequent shots will show no radial/concentric fractures.
3. Glass evidence collection
    a. Control samples from each section of broken glass should be collected.
    b. A piece of fractured glass (nontempered only) still remaining in the window should be marked to show orientation (outside/inside surface) and fracture edges (radial/concentric) and collected.
    c. Glass embedded in/adhering to bullets needs to be collected.
    d. Clothing from individuals suspected of being near glass struck by bullets needs to be collected.
4. Documentation of bullet holes in glass
    a. Measurement of bullet hole length/width should be recorded.
    b. Orientation of oblong holes, especially in windshield glass, should be recorded in terms of the cant of the long axis of the hole relative to a vertical.
    c. Close-up photographs with and without a scale should be taken.
5. Glass injury documentation
    a. Any apparent glass injuries on persons involved in shootings should be photographically documented.
    b. The pathologist should document and collect glass from deceased individuals.
6. Side glass position determination
    a. Examine upper window channels for the presence of glass fragments that would indicate that the window was up before breakage.
    b. Check the position of the lower window channel to establish window position.
7. Test firing for confirmation purposes
    a. Carry out test firing whenever appropriate and necessary (to confirm trajectories, ascertain hole characteristics, etc.).
    b. Test firing should be done as closely as possible to the same conditions as the shooting.

Bullet Holes in Tires and Other Elastic Materials

When bullets perforate elastic substrates such as tires and plastic vehicle body panels, the bullet hole created will be smaller than the bullet diameter owing to the elasticity of the material. This is somewhat analogous to the passage of a bullet through human skin. There is initial stretching followed by perforation and then elastic rebounding. During the passage of the bullet through the medium, scuffing of the outer margins occurs. This is analogous to the abrasion ring around the margins of a wound in human tissue. By measuring the diameter of the outer scuff ring, one obtains a reasonable approximation of the bullet diameter (caliber) that produced it. However, it is unwise to specify a specific caliber based on this information alone. A more cautious approach would be to merely specify the measured value. It is safe to presume that the bullet that produced the scuff ring was not significantly smaller in diameter. This is shown in Figures 12.30 and 12.31.

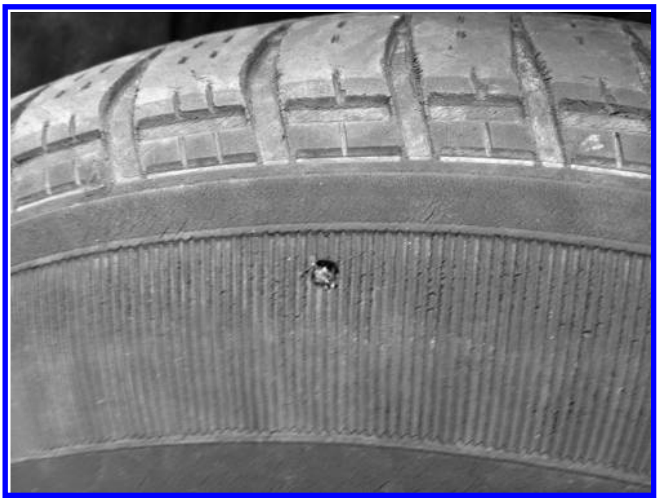


Figure 12.30 Hollow point bullet perforating tire sidewall.

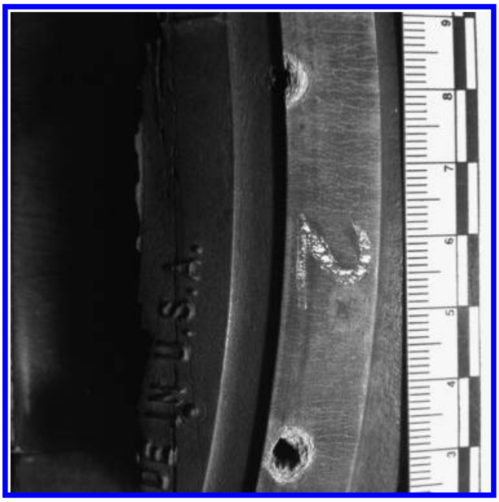


Figure 12.31 Visible scuff ring from hollow point bullet perforation.

Tires are often perforated or penetrated by bullets during shootouts. Depending on the particular bullet involved and the location of the entry/exit, these bullet holes can be difficult to find and misleading in appearance. A bullet hole in a tire sidewall produced by a round-nose .22 caliber bullet can be particularly misleading. A practical exercise involving such a defect is used by the author in shooting reconstruction classes provided to police agencies. It is quite common for students to opine that the defect was produced by an ice pick rather than a .22 caliber bullet. This is because the resultant bullet hole is quite tiny owing to the elastic rebound of the tire after perforation. This can be seen in Figure 12.32.

When hollow point bullets of larger caliber, say 9 mm, are used, there is typically a pronounced hole because of the “cookie cutter” effect of the hollow point. Thus, even when no bullet has been recovered, one is on pretty firm ground to speculate that a hollow point bullet produced a defect of this type. The abrasion collar produced as a result of the bullet stretching and abrading the outer margin can give some clue as to approximate bullet diameter (caliber). Although it is generally unwise to specify a particular caliber from such a measurement as already stated, one can at least proffer the measurement obtained. The result of a hollow point bullet being fired into a tire sidewall can be seen in Figures 12.30 and 12.31. Blunt nose bullets cause holes with more irregular margins.

When bullets are fired into the tread area of tires, it can be very difficult to locate bullet holes in some cases. If a vehicle that was part of a shootout has one or more flat tires, one would obviously want to have the wheel(s) removed and the tire(s) broken down to search for bullets and/or bullet fragments. It is also easier to identify bullet holes in tires from the inside. It is possible, however, to merely reinflate a tire and place it in a tub of water and look for the air bubbles in order to locate bullet holes.

If different bullet types are involved in a shootout where tire perforation has taken place, such as lead and jacketed bullets, it is possible to have the crime laboratory analyze the margins of the defect for lead, copper, antimony, aluminum, etc., and possibly determine which type of bullet produced the defect, assuming there are no other distinguishing features. This would have to be considered before inserting trajectory rods into the holes in tires.

The author has been involved in the investigation of several cases where police officers have shot out tires of suspect vehicles in an effort to stop the individuals from fleeing. The

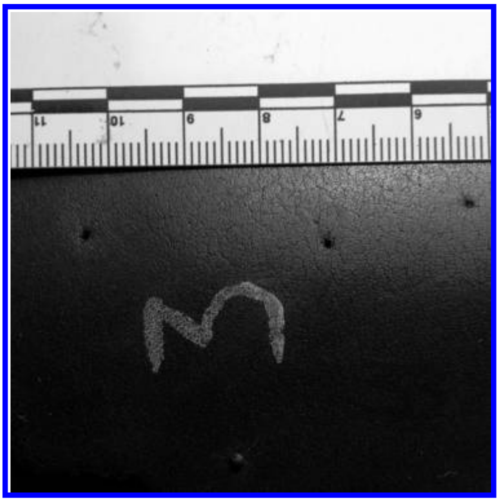


Figure 12.32 .22 caliber round nose perforations in tire sidewall.

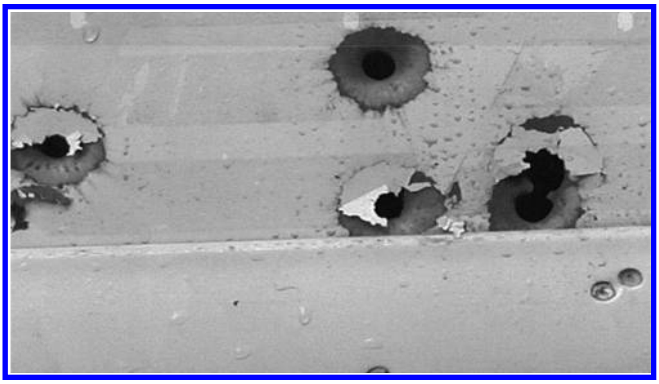


Figure 12.33 Shots into metal and plastic.

time required for a tire to go flat obviously involves a number of variables including location of the bullet hole in the tire (tread vs. sidewall), the size and construction of the tire, and the size of the hole produced. In numerous test firings conducted during the course of shooting reconstruction classes, this time has found to vary from as little as 5 seconds for an inexpensive 13-inch tire with two-ply sidewalls shot in the sidewall with a hollow point .40 caliber bullet to 15 minutes for a 15-inch pursuit tire of the type used by law enforcement, shot in the sidewall with a 9-mm round-nose bullet. Obviously, various other tire/bullet combinations can produce varying results. In any event, if an officer is standing in front of a vehicle and the shot is fired into the tire in an effort to stop the vehicle from striking the officer, the effort is ineffective.

Today's modern automobiles are produced with numerous body panels, moldings, and covers made of plastic. As with tires, bullet holes will be smaller than the diameter (caliber) of the bullets that produced them. The investigator should not confuse bullet holes in plastic parts located near larger-appearing bullet holes in sheet metal as resulting from different caliber weapons. This situation is illustrated in Figure 12.33.

The difference is obviously very pronounced, and it is easy to see why one might think different calibers were involved. The key is to remove the plastic piece and look behind it for secondary impact to inelastic media.

Documentation

As with all physical evidence associated with a crime scene, proper documentation of bullet holes and wounds is critical to the reconstruction effort. The basic principles of crime scene documentation apply here: sketch and photograph. The documentation of wounds will typically reside with the pathologist. Most medical examiner's offices are well equipped to take appropriate photographs. When this is not the case, the investigator must take the responsibility for scale photography, as illustrated in Figure 12.34.

Certainly, all pathologists will document wound locations according to accepted forensic protocol. These measurements will become critical when bullet holes in clothing are to be reconciled with wound locations as in the previously discussed Trayvon Martin case. In the ideal case, of course, the criminalist and the pathologist would be working in concert to make these kinds of evaluations at the time of autopsy.

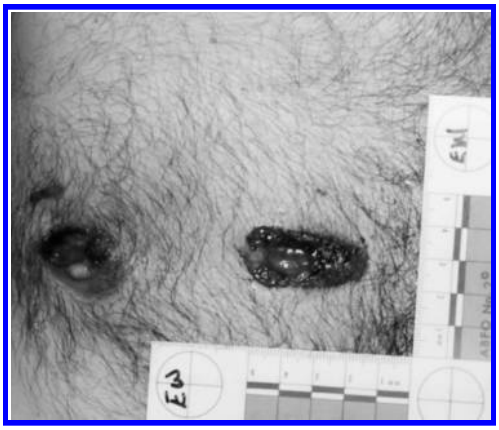


Figure 12.34 Graze wound to chest.

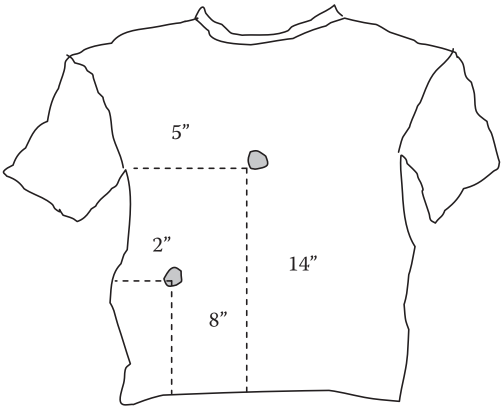
The basic rules of crime scene photography must be followed (see Chapter 19). Overall photographs are followed by close-up views. A scale is included in all close-up photographs as well as some indicator as to which hole/wound is being photographed and its orientation. In the case of clothing, it is often advisable to place a piece of card stock behind the bullet hole so that it can be seen in the photograph. Otherwise, the hole is lost in the surrounding cloth.

Sketches should be made of all clothing items. Sketches should include measurements that designate the position of all bullet holes. An example of the type of sketch that should be made is shown in Table 12.7. Sketches should be included in bench notes as a backup for photographs.

Similar sketches should be made for windshields and windows. It is particularly advisable to include indicators of shot directionality, such as beveling, in sketches.

Table 12.7 Documentation of Bullet Holes in Clothing

T-Shirt



1. Designate bullet holes by number or letter.
2. Establish the distance from the bullet hole to the hem line (or furthest point to bottom).
3. Establish a horizontal distance to fabric edge.
4. Repeat for each bullet hole.
5. Prepare a table of measurements for front and/or back, sleeves, and sides as appropriate.

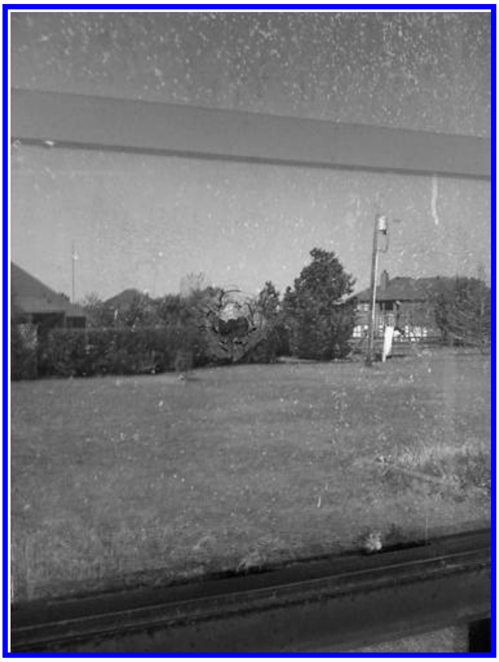


Figure 12.35 Bullet hole in center obscured by background.

Photographs of bullet holes in glass can be challenging because of the reflective nature of glass. The use of a detachable flash so that oblique lighting can be achieved is mandatory. Many times, however, available light is satisfactory by itself. The beauty of digital photography is that all of this can be determined at the scene and appropriate accommodations made.

In some instances, the use of black construction paper behind the glass is necessary to eliminate the transparency and its associated problems. The investigator should carry black construction paper in with the photography equipment. The construction paper can be taped or held behind the piece of glass with the bullet hole. This technique is particularly useful in photographing bullet ricochet marks on glass, as will be discussed in the next chapter. Special considerations in documenting bullet holes in vehicles are discussed in the section "Shots Fired into Vehicles" in Chapter 16. The problem is illustrated in Figure 12.35.

Case Study

Two undercover officers were involved in a drug sting operation that took place during daylight hours at a local fast-food restaurant in a large, metropolitan area. The officers had walked up to the small, economy vehicle in which two suspects were waiting that was backed into a parking space at the restaurant. According to the plan, once the officers got near the vehicle the bad guys were in, two Chevrolet Suburbans occupied by backup officers were supposed to pull up and block the bad guys in. As it turned out, once the Suburbans pulled up and the lead officers drew their weapons, the bad guys started up their car and attempted to drive through the partially open space. The lead officers, in fear for their lives and those of the other officers and innocents nearby, opened fire on the bad guys. Multiple shots were fired through the windshield of the car they were attempting to drive through with (Figure 12.36).

It should be noted that, as previously described and illustrated, the placement of black construction paper inside behind the windshield would have greatly enhanced the visibility of the bullet holes. As a result of a civil suit filed against the police agencies involved, it became necessary to determine where both of the officers had been firing from. As it turned out, the escape vehicle had physics working against it and was unable to push the two hefty Suburbans aside, once again proving that size does matter. However, the front wheel would-be escape vehicle literally burned up its front tires spinning aimlessly and creating two deep ruts in the asphalt in the process (useful for re-creation at a later date). The plaintiffs alleged that the officers had inappropriately shot and killed the two occupants when it should have been obvious that they were going nowhere.

Measurements were taken of the side-to-side angles of the bullet holes in the windshield as described earlier in this chapter. Next, a similar windshield was obtained and test firing was conducted to confirm the fact that both officers, while not directly in front of the bad guys' vehicle, were close to the front (see Figures 12.37 through 12.39).

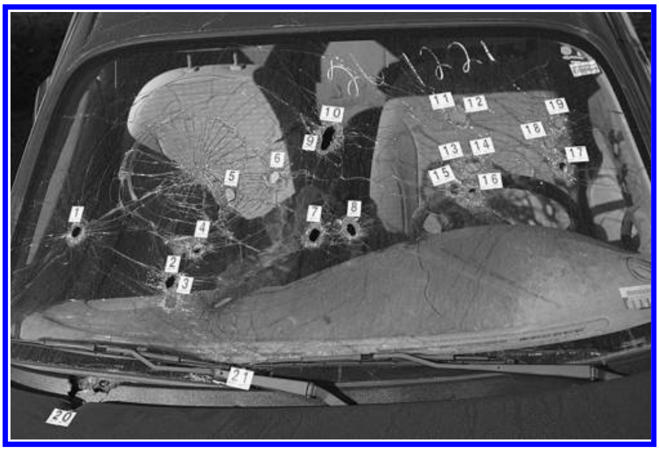


Figure 12.36 Windshield of car.

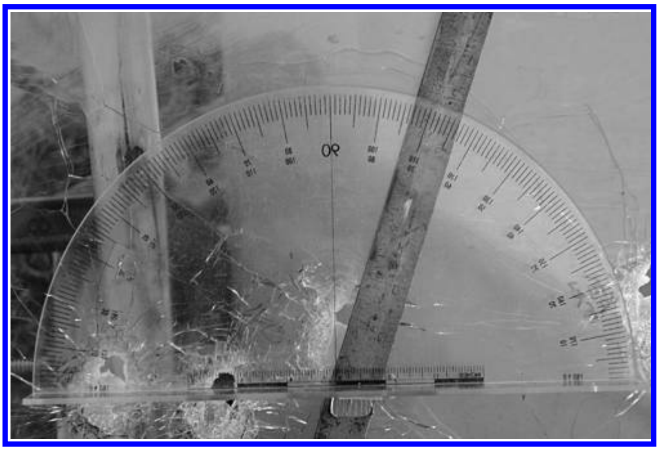


Figure 12.37 Bullet hole lateral angle measurement.

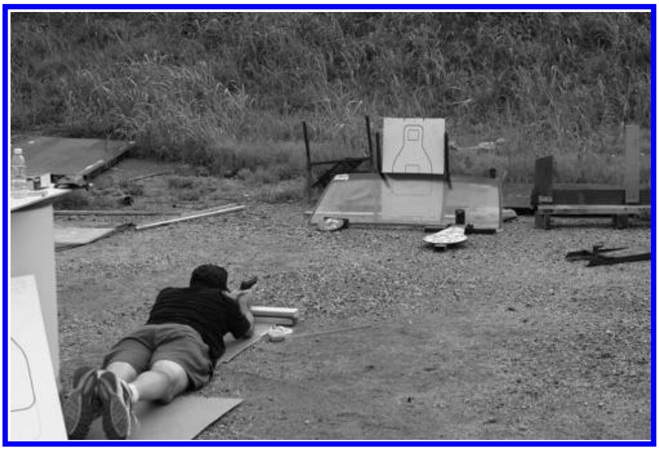


Figure 12.38 Test firing.

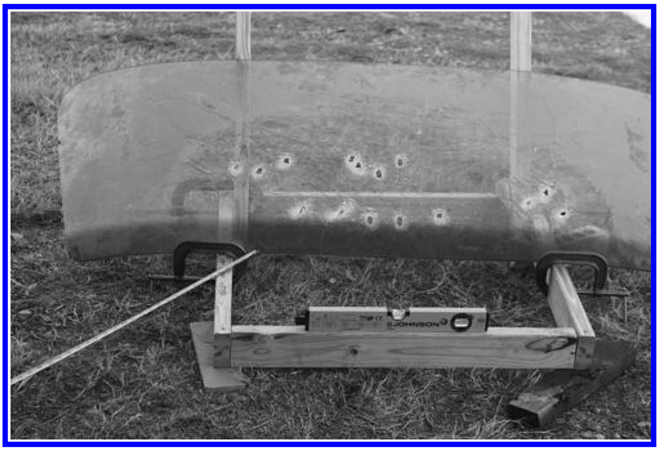


Figure 12.39 Evaluation of test results.

Exercises

1. A bullet hole is found in a tempered glass window (Figure 12.40). How can it be determined whether the shot was fired from inside the vehicle?

   Answer: The side that has a beveled margin is the exit side.
2. Two bullet holes are found in the windshield of an automobile. Can it be determined which shot was first?

   Answer: If multiple radial fractures intersect, sometimes the bullet hole with the radial fracture that dead ends into the radial fracture associated with the other hole had to be the second shot, but that can also be the result of unrelated events such as loading and towing after the incident.
3. An autopsy report states "No soot or powder particles were found in or around the wound." What, if anything, should be done with overlying clothes from the victim?

   Answer: Two things should be done: first, the clothing needs to be submitted to the crime laboratory for examination and testing for gunshot residue. Second, the bullet hole locations in the clothing need to be compared to the location of the wounds.

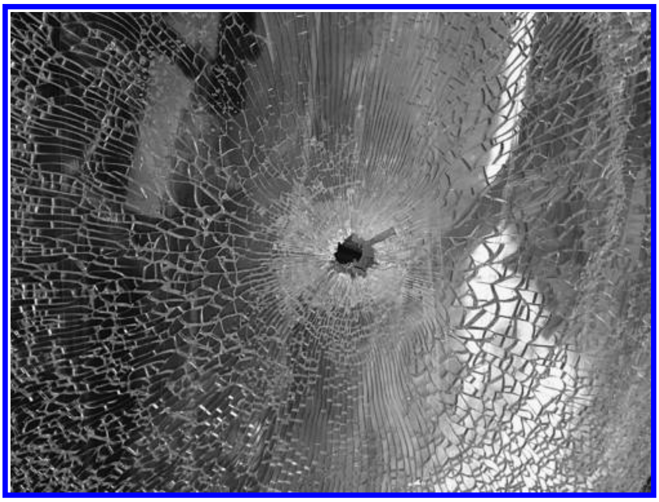


Figure 12.40 Shot through tempered glass.

4. A tiny hole in a tire sidewall is found after a shootout. The hole does not appear to have been caused by a bullet because of its small size. Should anything further be done with the tire?

   Answer: Yes, the tire needs to be removed from the rim to determine if a bullet or bullet fragments can be located. The small hole may well be a bullet hole produced by a small caliber, round-nose bullet such as a .22 caliber bullet.
5. A shooting incident involving a vehicle takes place, and there is a question as to whether a particular individual was standing near a vehicle during the shooting. The windshield of the vehicle was struck numerous times by bullets. What, if anything, can be done to attempt to make a determination as to the man's proximity to the vehicle?

   Answer: The man's clothing needs to be collected and submitted to the crime laboratory along with a sample of glass from the windshield. The impact of a bullet with glass produces a shower of tiny glass fragments that might get deposited on the man's clothing if he was standing close to the windshield when the bullets struck.
6. A police officer stated that he was standing in the proximity of the front of a vehicle as he was attempting to get a suspect out of the vehicle. He further stated that the person started the vehicle and started driving toward the officer. The officer stated that he then shot the left front tire in an effort to stop the vehicle. How effective would that have been?

   Answer: Shooting a tire is ultimately going to cause all but "run flat" tires to go flat eventually. The reality, however, is that 10–15 seconds or more would be involved and the officer would not be able to prevent the vehicle from striking him by that action alone.
7. A shooting incident takes place in which a door glass of a vehicle is shot out by an officer. Broken glass from the door glass is found in the street several yards from the officer's stated position. Is the officer lying or maybe does not recall his actual position?

   Answer: Probably neither is true. Glass in vehicle side windows shot through in the course of a shooting incident will often hold together as the vehicle continues to travel along. Ultimately, the effect of vibration or a secondary impact will likely cause the glass to finally fall out. Thus, it is not uncommon for glass to be found at a position different from the point of bullet impact.

8. Two bullet holes are found in a tire sidewall (Figure 12.41). They have a different appearance. What likely accounts for the difference in appearance?

   Answer: The larger, circular opening is consistent with a hollow point bullet, and the other is a nonhollow point (e.g., blunt nose, round nose).
9. Examine the image of a bullet hole through tempered glass (Figure 12.42). What can you conclude about the responsible shot?

   Answer: This is clearly not the first shot because there are no radial or concentric fractures associated with the hole.
10. Figure 12.43 represents what not to do in a shooting reconstruction. Albeit somewhat tongue in cheek as presented here, the safety aspect of dealing with firearms should always remain at the forefront.

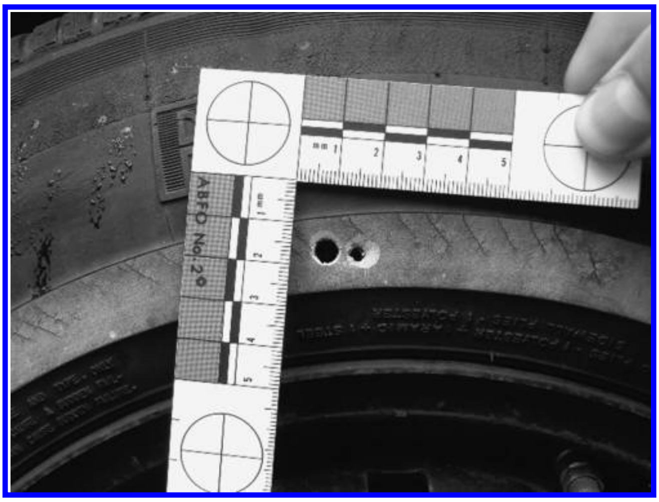


Figure 12.41 Bullet holes in tire sidewall.

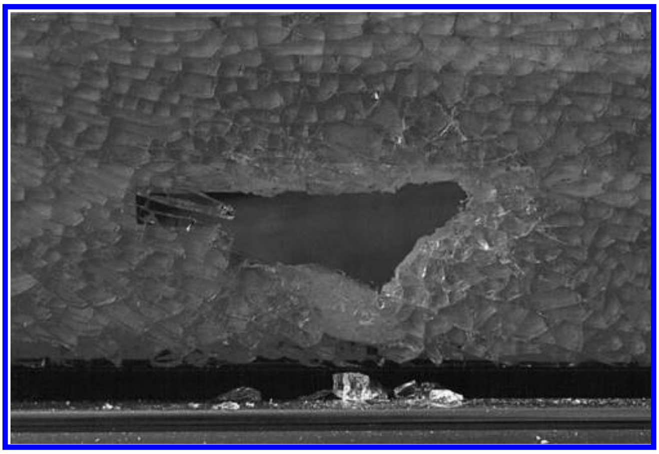


Figure 12.42 Bullet hole in tempered glass.

Figure 12.43 Never do this! (Shoot yourself in the foot–figuratively or literally!)

Suggested Readings

Alakija, P., Dowling, G.P. and Gunn, B., Stellate Clothing Defects with Different Firearms, Projectiles, Ranges and Fabrics, Journal of Forensic Sciences, Vol. 43, No. 6, November 1998, pp. 1148–1153.

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Bullet Ricochet Phenomena

13

Ricocheting bullets are not desirable under any circumstance, but particularly so in tactical situations where police officers are involved (Figure 13.1). Unfortunately, ricochets are quite common in shooting incidents, particularly those that take place outdoors. To be able to reconstruct shootings in which ricochets are involved, one must understand the phenomenon and be able to recognize the indicators of directionality and other information that might be present. Although ricochet studies have been conducted on a wide variety of substrates and reported in the literature, specific information regarding directionality determination for a given substrate/bullet combination may require carrying out test firing.

A review of the basics of ricochet phenomena is pertinent in order to facilitate a discussion of the information that may be offered to the watchful eye of the investigator. First of all, a few working definitions are essential.

Ricochet Terminology

Ricochet—a change in angle and/or direction of a fired bullet/pellet as a result of impact with a substrate

Ricochet mark—a two-dimensional effect without discernible depth (such as a ricochet off a piece of flagstone without surface penetration)

Ricochet crease—a three-dimensional effect with discernible depth (such as a ricochet off an automobile hood)

Angle of impact—the angle of incidence of the impinging bullet/pellet to the substrate

Angle of deflection—the lateral deflection of the ricocheting bullet/pellet (a result of spin stabilization—either to the right or left depending on rifling direction)

Angle of ricochet—the angle of departure of the departing bullet/pellet as it leaves a substrate

Critical angle—the angle at or below which a ricochet would be expected for a given bullet/pellet and a given substrate

Frangible surface—surface that is subject to crumble or break upon application of force (such as asphalt and concrete)

Nonfrangible surface—surface that tends to bend or stretch upon application of force (such as sheet metal)

Conditions Conducive to Ricochets

Ricochet is a phenomenon of low rather than high velocity. This is because high-velocity bullets, such as a .223 caliber traveling at, say, 2800 feet per second, have a propensity to fragment on impact rather than be deflected off. This, of course, depends a lot on the bullet design and composition as well as the substrate composition in addition to other variables.

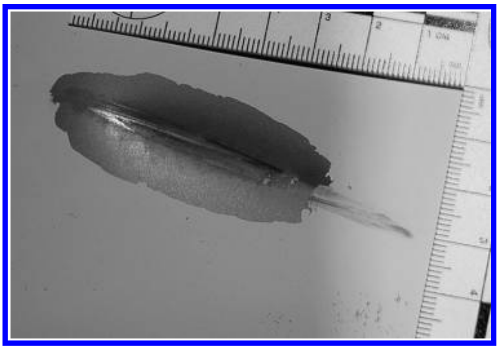


Figure 13.1 Ricochet.

However, in general, we expect large, slow-moving bullets to be deflected off various substrates more frequently than small, high-velocity bullets impacting the same substrate. As always, there are going to be exceptions depending on the specific circumstances involved. Although ricochet phenomena are most often discussed for bullets, certainly pellets and spherical shot can and do ricochet off surfaces as well.

In order for a bullet/pellet to ricochet off a given substrate, it must impinge at or below the critical angle (the angle at or below which a ricochet is predicted). The critical angle must be determined for a particular bullet and substrate through testing. There are published studies concerning critical angle determinations in the literature, but in order for them to be of specific value to an investigator involved in reconstructing a shooting that same exact substrate, bullet, cartridge, and weapon would have to have been used. The chances of that happening are pretty slim. Thus, test firing under like conditions, when practical, is always the best bet.

With regard to the appearances of bullet ricochet marks and creases, a few general statements may be made.

- Ricochet marks and creases may be produced on virtually any surface.
- The harder the surface, the smaller the ricochet angle.
- The lower the angle of impact, the longer the ricochet mark/crease.
- The lower the angle of impact, the more likely that a mark rather than a crease will be produced, all else being equal.

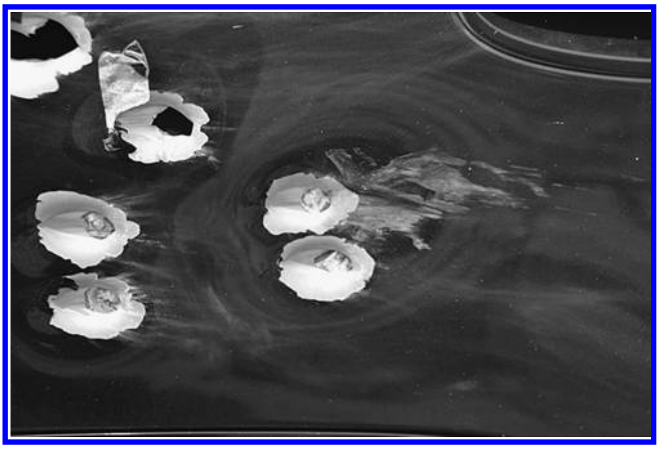


Figure 13.2 00 buckshot ricochet off car door.

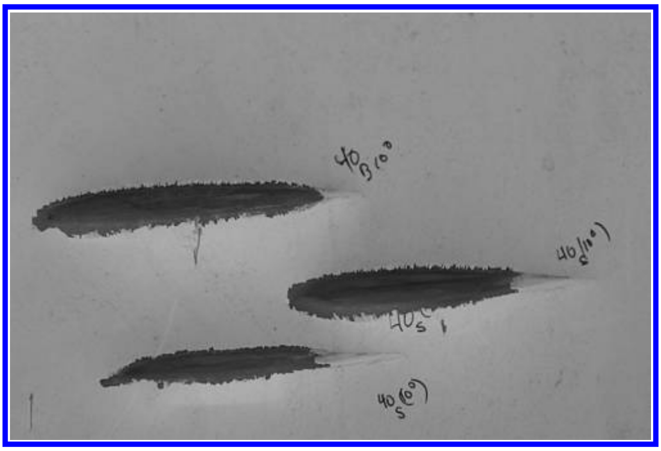
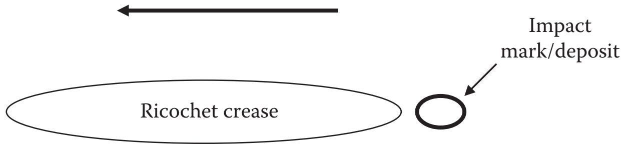


Figure 13.3 Ricochet creases off sheet metal (right to left directionality).

With regard to ricocheting spherical pellets (e.g., 00 buckshot, #7 1/2 birdshot), the fact that there is no induced spin stabilization (i.e., no rifling in the shotgun barrel being used) means there will be no inherent deflection left or right, and the resultant ricochet mark on nonyielding surfaces will be symmetrical. This is illustrated in Figure 13.2.

Directionality Based on Point of Impact

Directionality of bullet/pellet travel from ricochet marks/creases can often be ascertained by a variety of other indicators. Bullets and pellets often leave visible deposits of lead/copper at the point of initial impact for a ricochet crease/mark. This is a ready source for establishing directionality. This is often a rather distinctive mark/deposit as represented in Figure 13.3.



Other Indicators of Directionality

The "V" Shape

When lead or lead nose bullets and lead pellets strike hard surfaces at very low angles producing ricochet marks, the shape of the marks can aid in determining shot directionality. A "V"-shaped deposition of lead will sometimes be seen. The shot directionality goes from the vertex of the V toward the top of the V. This pattern is a result of the ever-increasing contact between the bullet or pellet with the substrate and the resultant deformation of the bullet/pellet. This effect tends to be more pronounced for bullets as compared to shot pellets as a consequence of shape (elongated vs. uniform).

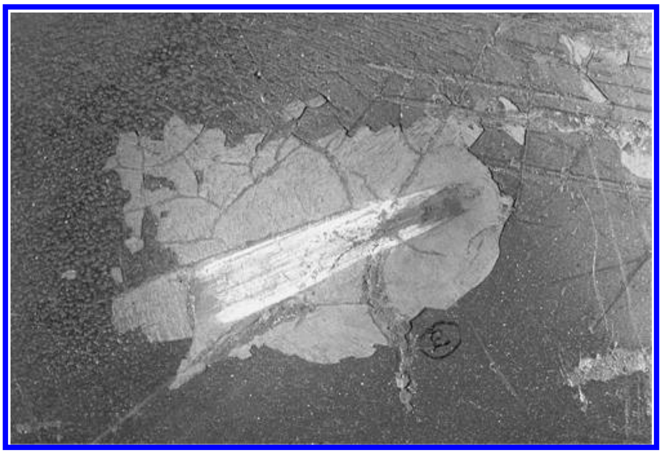
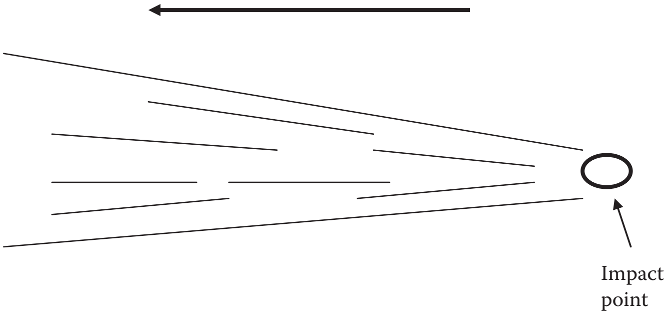


Figure 13.4 V shape (right to left directionality).



An actual example is shown in Figure 13.4.

Fracture Lines in Painted Surfaces

When painted metal surfaces are impacted by bullets/pellets, stress fractures will often be produced. Shot directionality is often easy to ascertain from the fracture line patterns. The direction of force will, of course, be the same as the shot direction. As the force emanates through the paint layer, cracks will be produced that resemble the wake coming off the hull of a boat moving through water (Figure 13.5).

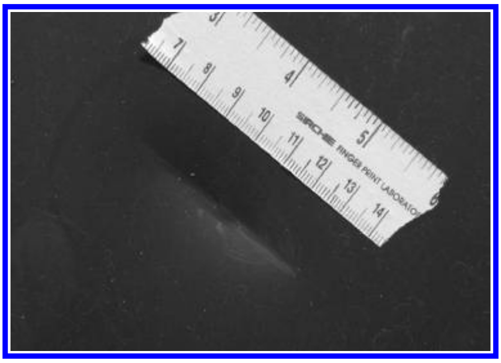
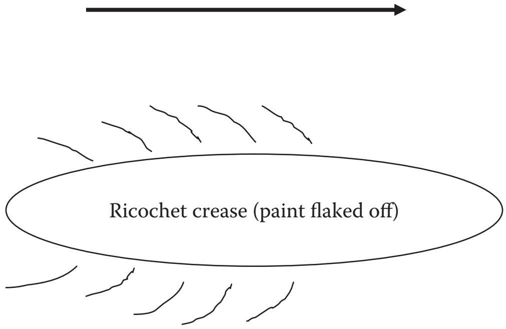
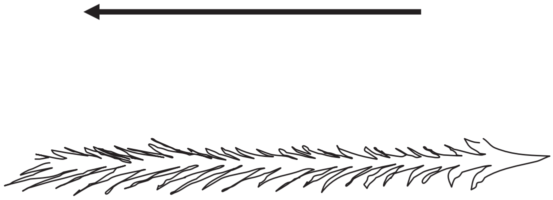


Figure 13.5 Stress cracks in paint (left to right directionality).

Even when all the paint flakes off in the immediate area of the ricochet crease, stress marks may be visible at the outer margins of the ricochet crease.



It is also possible for the stress fracture pattern to show up on the underside of a ricochet crease in painted sheet metal. An interesting phenomenon is observed in these instances. A "reversed directionality" of the stress fracture pattern is produced. This is represented in Figure 13.6.



The "reverse directionality" phenomenon on the underside of bullet/pellet ricochet creases in painted sheet metal can be extremely useful when difficulty in establishing shot directionality is encountered for the upper surface. Of course, gaining access to the under surfaces of bullet ricochet creases can be complicated by the structure of the material and/or the presence of other obstacles. This is particularly true with vehicle body panels that usually have structural bracing. Nonetheless, this is something that the investigator should be aware of and look for when possible. A somewhat unusual example is presented

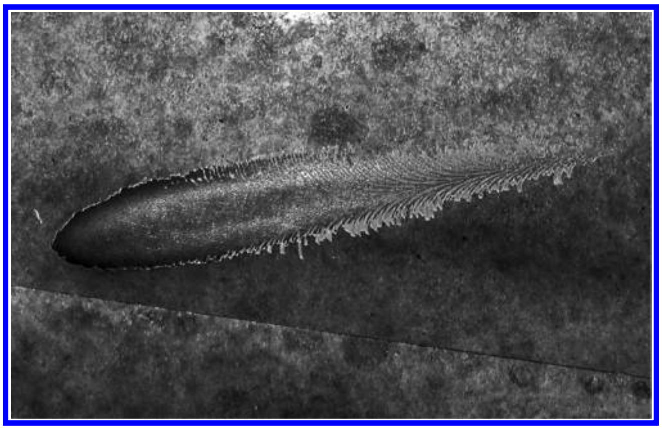


Figure 13.6 Tree effect (right to left directionality).

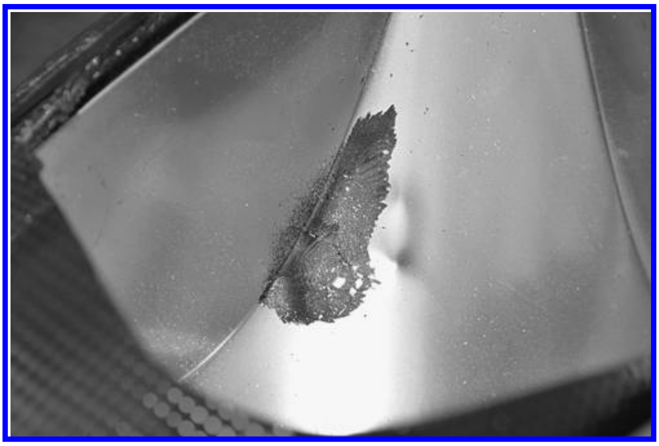


Figure 13.7 Internal ricochet (bottom to top directionality).

in Figure 13.7, which shows the inside of a taillight housing that a bullet ricocheted off after impacting the housing outer surface.

"Classic" Ricochet Mark

The rounded edge of a ricochet crease or mark, when present, is a good indicator of directionality. This is the point at which the bullet first impacts the substrate and begins to change course. The rounded edge will define the directionality of the ricochet. This is probably the most commonly seen ricochet mark for round-nose lead bullets (Figure 13.8).

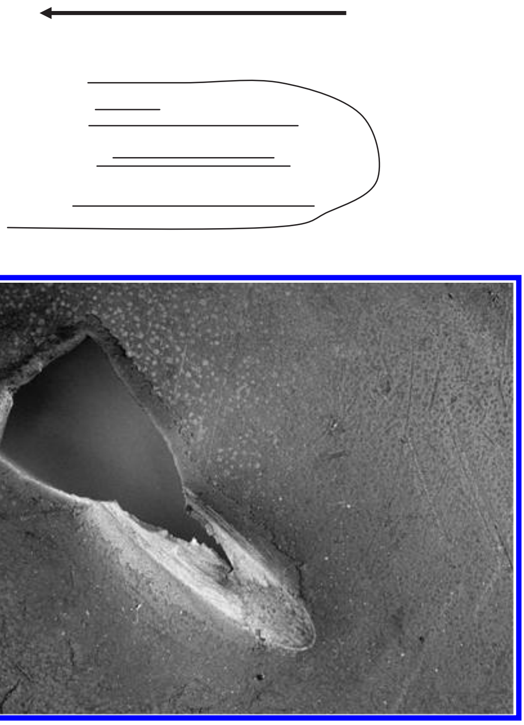


Figure 13.8 Classic rounded ricochet mark (right to left directionality with partial penetration).

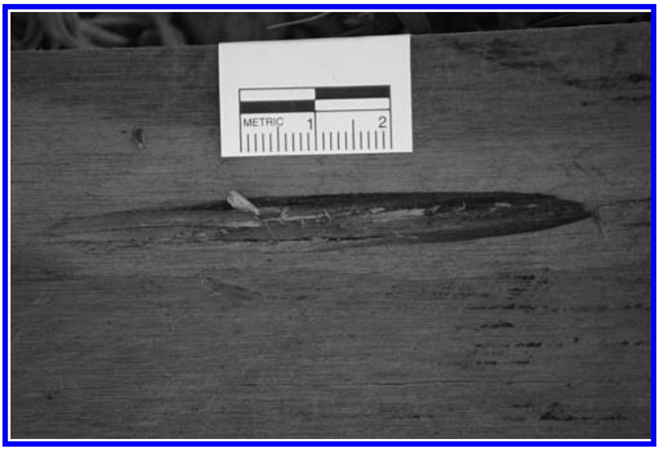


Figure 13.9 Ricochet off wood; directionality is dark end (right) to light end (left).

In the event that the ricochet mark/crease is uniform in appearance (both ends look the same) and no other indicators are present, the directionality must be classed as indeterminate. This is illustrated in Figure 13.9 (uniform appearance), but the dark end is the initial point of impact as grease/soot gets wiped off the bullet by the substrate.

The "Pear" Effect

Ricochets off painted sheet metal (i.e., automobile body panels) often result in paint being flaked off in a "pear" shape (Figure 13.10). The directionality will be from the top of the "pear" toward the bottom. Lead and/or copper transfer at the point of impact may also be present to simplify the determination of directionality. Even when a true "pear" shape is not present for the flaked-off paint, more paint will typically be missing on the exit end of the ricochet crease (ricochet marks typically do not produce paint flaking). The direction of force will be the same as the direction of bullet travel. The source of this particular phenomenon is simply the mechanical disruption of the paint by the impacting bullet. Thus, more paint will be typically lost on the exit end because of the force going in that direction.

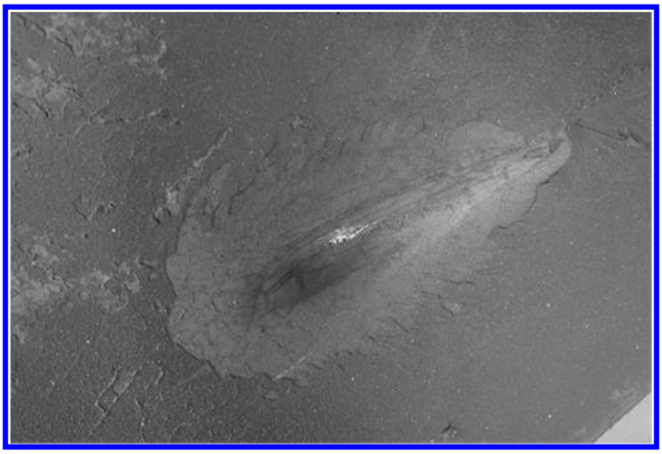
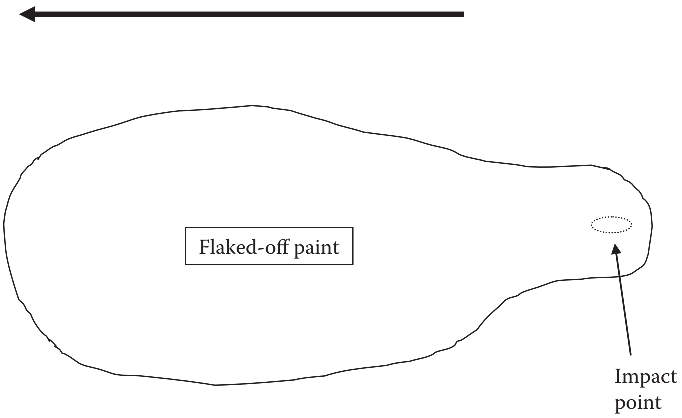


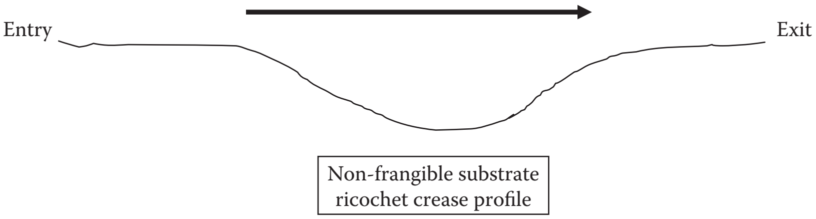
Figure 13.10 Pear effect (right to left directionality).


Flaked-off paint
Impact point

This is also illustrated in Figure 13.10.

Ricochet Crease Profiles

The profile of a ricochet crease may aid the investigator in establishing directionality. For nonfrangible surfaces, such as sheet metal, bullet impact produces stretching of the metal. This stretching results in the greatest depth at the exit end of the ricochet crease. This profile is represented below.


Entry
Exit
Non-frangible substrate ricochet crease profile

This can also be seen in Figure 13.11 for a ricochet off sheet metal.

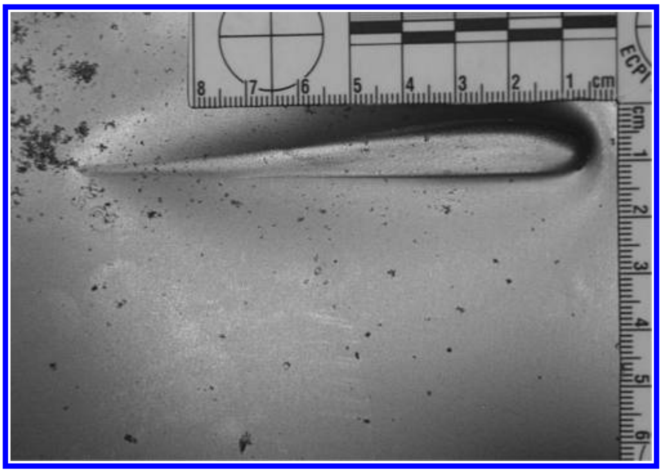


Figure 13.11 Ricochet off sheet metal (shallow to deep directionality).

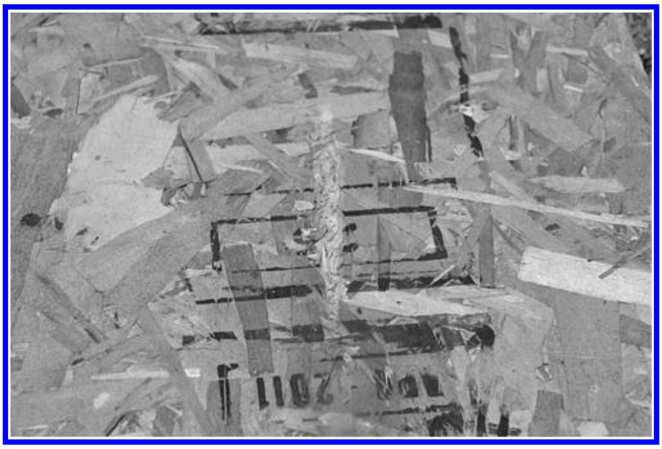
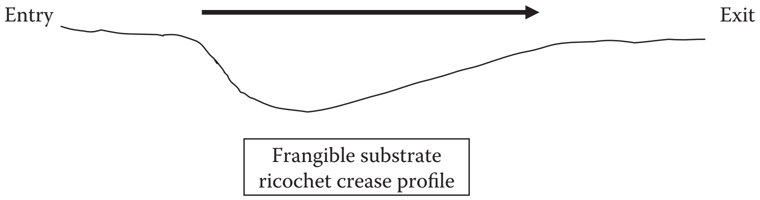


Figure 13.12 Ricochet off frangible wafer board (deep end at the bottom is the entry end).

With frangible surfaces, such as asphalt, the greatest depth is typically at the entry end. The impacting bullet dislodges bits of the frangible substrate and pushes it forward. Thus, the exit end has less depth than the entry end, as illustrated below.



This is also illustrated in Figure 13.12 for a wafer board.

Ricochet with Partial Penetration

Because of the thin sheet metal now used in the manufacture of automobiles in the interest of reducing weight for improved fuel economy, bullets often show partial penetration as well as ricochet. Other substrates, such as windshields, may show this phenomenon as well. If the bullet fragments, a portion may actually penetrate the substrate. When there is partial penetration with steel vehicle body panels, the inner surface of the ricochet crease will usually have metal “fingers” that point in the direction of travel of the bullet. In other words, the bullet pushes the torn edges of metal in the direction that it is traveling. This is shown in Figure 13.13.

Internal Ricochet

It is not uncommon for bullets to penetrate vehicle body panels only to strike an internal brace or other obstruction and ricochet internally. This is obvious because of the protrusion that is created. Sometimes, the “Christmas tree” effect previously described will be visible, but usually no determination as to directionality is possible without being able to view the internal surfaces of the panel (Figure 13.14).

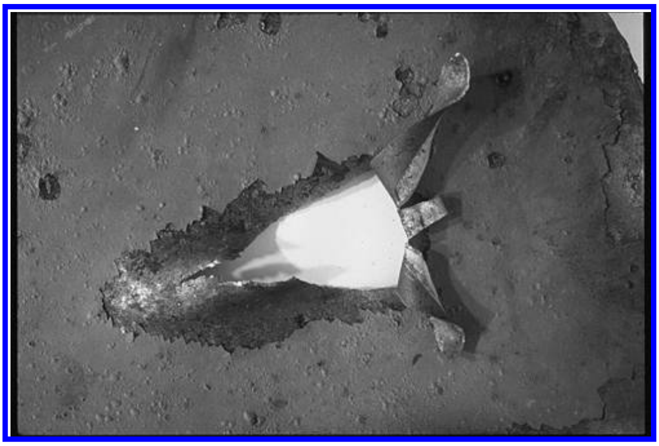


Figure 13.13 Underside of ricochet with partial penetration.

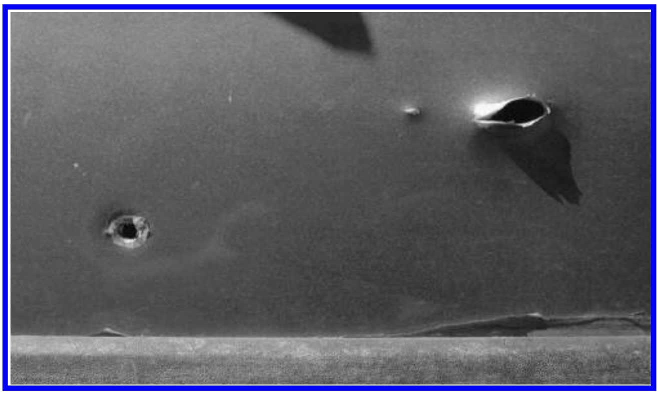
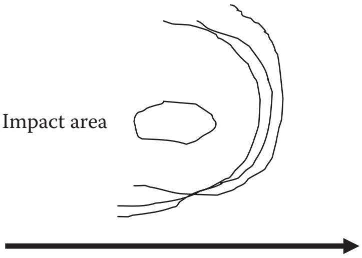


Figure 13.14 Internal ricochet.

Ricochets off Glass

Both creases and marks can be produced by bullets ricocheting off glass. This is typically a phenomenon only observed on safety plate (laminate) glass as found in vehicle windshields. Tempered glass, as found for the side and rear glass of vehicles, is designed to shatter into small rectangular solids on impact and, thus, does not typically allow visualization of ricochet marks/creases although they can sometimes be found.

Ricochet creases in glass will sometimes produce a "jellyfish" effect for the stress cracks that will allow directionality to be established. The theory here is simply that the stress cracks follow the force direction. This is illustrated below.



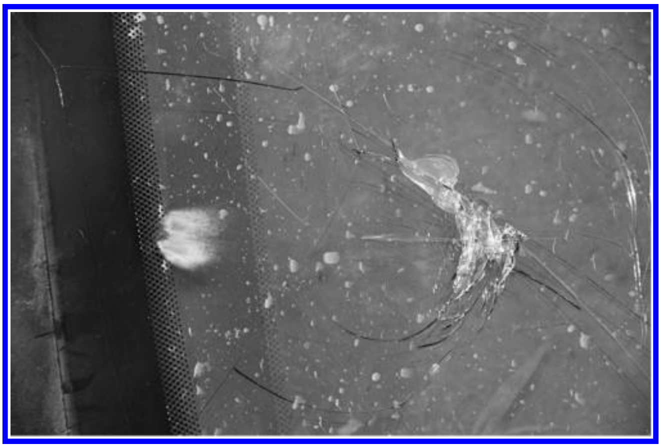


Figure 13.15 Ricochet off glass with fracturing (left to right directionality).

An actual example can be seen in Figure 13.15.

In some instances, the stress cracks will be circular (surrounding the impact area), making directionality determination on this basis impossible.

Ricochet marks on glass are frequently difficult to locate and rather fragile (rubbing across them can obliterate them). A ricochet mark on glass is shown in Figure 13.16.

In one case in the author's experience, however, a very prominent ricochet mark was produced on tempered glass from a .45 Federal Hydra-Shok© that resulted in the transfer of both copper and lead. Directionality was clear from the "classic" rounded edge at the point of impact.

Unfortunately, the crime scene examiner who astutely recognized the significance of the mark and collected the fragment of glass it was on was unable to determine its original orientation in the rear glass. This rather unique mark is shown in Figure 13.17. The really interesting aspects of this mark are the visible striations and the combination of copper and lead residue. The striations appear to possibly be of sufficient quantity to allow identification of the responsible bullet (if one could be located).

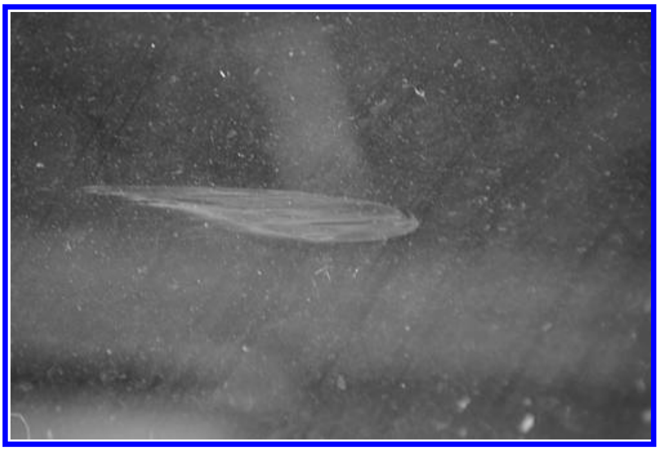


Figure 13.16 Ricochet off glass without fracturing (right to left directionality—bullet had right twist).

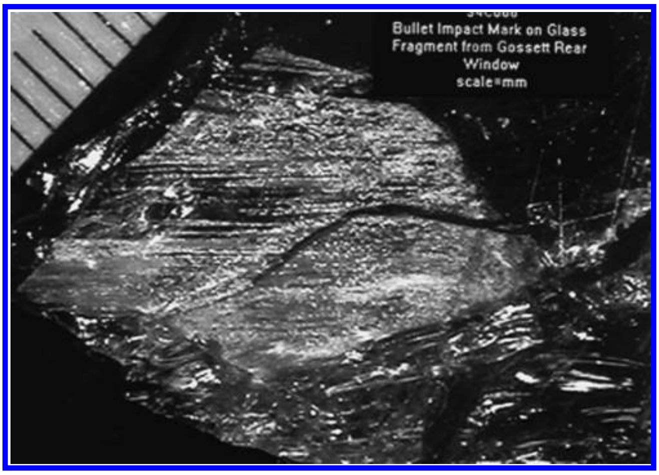

Bullet Impact Mark on Glass
Fragment from Gossett Rear
Window
scale=mm

Figure 13.17 Ricochet mark on tempered glass (right to left directionality).

Perhaps even more surprising than the actual persistence of this particular mark on tempered glass is the existence of what appear to be individual characteristics transferred from the rifling marks on the bullet that produced the mark. This particular subject is further discussed in the next section.

Direction of Twist Determination from a Ricochet Mark

Bullets fired from rifled weapons will either be rotating clockwise or counterclockwise depending on the direction of twist of the rifling in the barrel. It is possible to distinguish twist direction from a ricochet mark produced on certain surfaces as well as accurately predict shot direction.

The ricochet mark associated with the particular rifling present in the barrel of the weapon used is visible in Figure 13.16 (the tailing to the right results from right-hand twist), and this is shown schematically in Figure 13.18. These marks are most often found on hard surfaces such as steel or concrete. To assess these types of ricochet marks, the investigator should look at the mark from directly above the mark. The dashed lines represent the axes

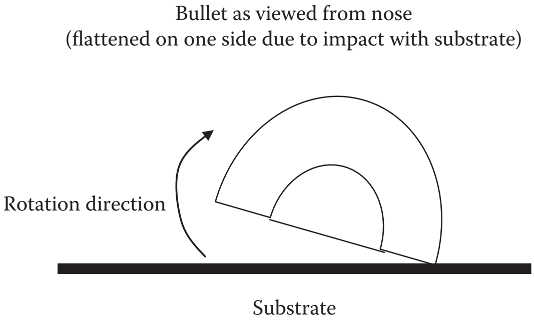

Bullet as viewed from nose
(flattened on one side due to impact with substrate)
Rotation direction
Substrate

Figure 13.18 Ricochet mark tail production.

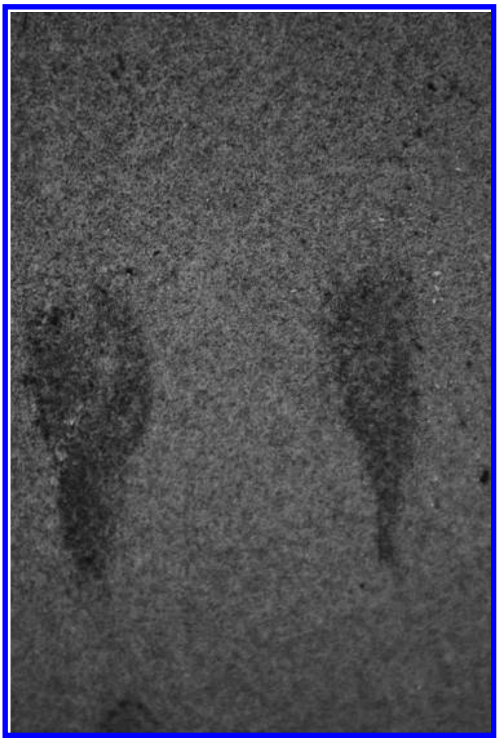


Figure 13.19 Left twist mark (right) and right twist mark (left)—both responsible bullets were going top to bottom.

of the two marks. Bullets with right twist produce ricochet marks with a "tail" to the right of the long axis of the mark. Conversely, bullets with left twist produce a "tail" to the left of the long axis of the ricochet mark. These "tails" that are observed for ricochet marks are a consequence of the bullet having been flattened by the initial impact with a substrate and continuing to rotate as it departs the substrate. This is illustrated in Figure 13.19, where the view is directly into the nose of the oncoming bullet as it starts to depart (ricochet off) the substrate.

The lateral deflection of bullets in correspondence to the rifling direction of the barrels from which they are fired is readily observed in water traps for test fired bullets. Firearm examiners find that bullets with right twist tend to deflect to the right in the water trap and vice versa for bullets with left twist. This can also be demonstrated rather graphically using tracer ammunition, such as the readily available Hornady Vector™ ammunition, to produce ricochets with visible paths. The lateral deflection is illustrated in Figure 13.20 (all in a single plane).

It is fairly common, in the author's experience, to find rifling marks left in ricochet marks/creases in a variety of substrates. The author has been involved in several cases in which rifling marks found in ricochet creases were used to include certain weapons as having possibly fired the ricocheting bullet and to exclude others. It remains to be seen as to whether an actual identification might be possible from a ricochet mark or crease.

This phenomenon appears most often when painted metal surfaces are involved. However, as described above in the section "Ricochets off Glass," these general rifling

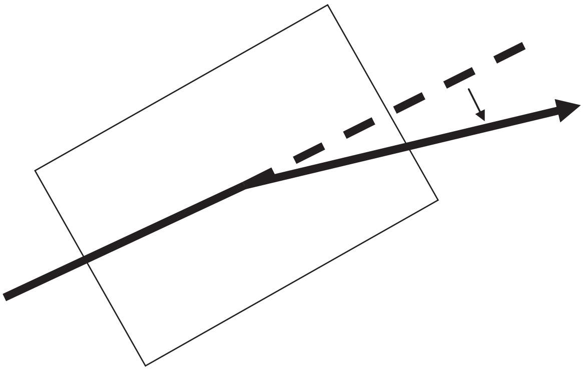


Figure 13.20 Lateral deflection of ricochet.

characteristics can and do appear on various substrates and should always be looked for by the investigator. The investigator must bear in mind that the ricochet mark or crease is actually a negative of the bullet surface. Thus, when rifling impressions can be seen, the direction of twist seen in the ricochet crease or mark will be just the opposite of the twist direction of the bullet that created it. The comparison of rifling marks in a ricochet crease to the rifling marks on a bullet is illustrated in Figure 13.21. A schematic is shown in Figure 13.22.

The documentation of rifling marks in bullet ricochet marks/creases requires that this evidence not only be photographed, but that a cast of the mark/crease also be taken using Mikrosil™ or some other suitable casting medium. This is necessary in order for the firearm examiner to be able to properly measure the rifling dimensions present. It can also be useful for assisting in determining directionality by providing profile information. This is particularly critical for ricochet creases because they are three dimensional. Taking a photograph without casting would fall short of properly documenting the evidence.

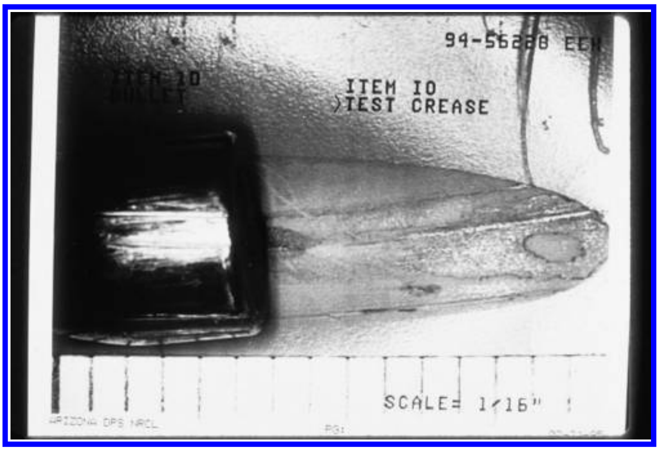


Figure 13.21 Rifling marks in a ricochet crease and on the responsible bullet (mirror images of each other).

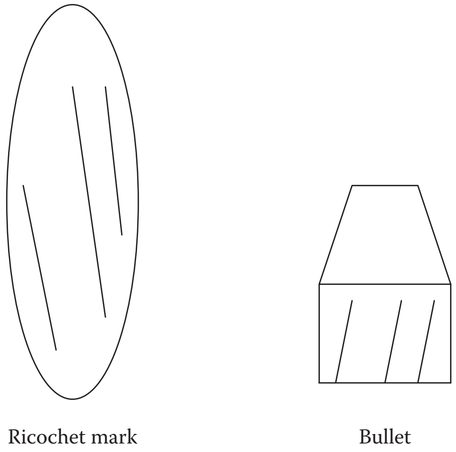

Ricochet mark
Bullet

Figure 13.22 Rifling marks in ricochet crease and bullet.

Establishing Critical Angles

In some instances, it may be necessary to establish what the critical angle is for a given bullet and substrate combination. This is done through field testing in which the weapon involved in the shooting under investigation is fired using cartridges or shot shells like those used in the actual shooting. A portion of substrate from the actual shooting scene is preferable; however, similar substrate may be used if necessary.

Other equipment required includes a machine rest for the weapon (Zero One™, Ransom Rest™, or other), a table or fixture to hold the substrate in place, and a target or witness panel. It is typically easier to mount the weapon in the machine rest and have that assembly perpendicular to the substrate and adjust the angle of impact at the substrate rather than adjust the angle at the weapon. This is illustrated schematically in Figure 13.23

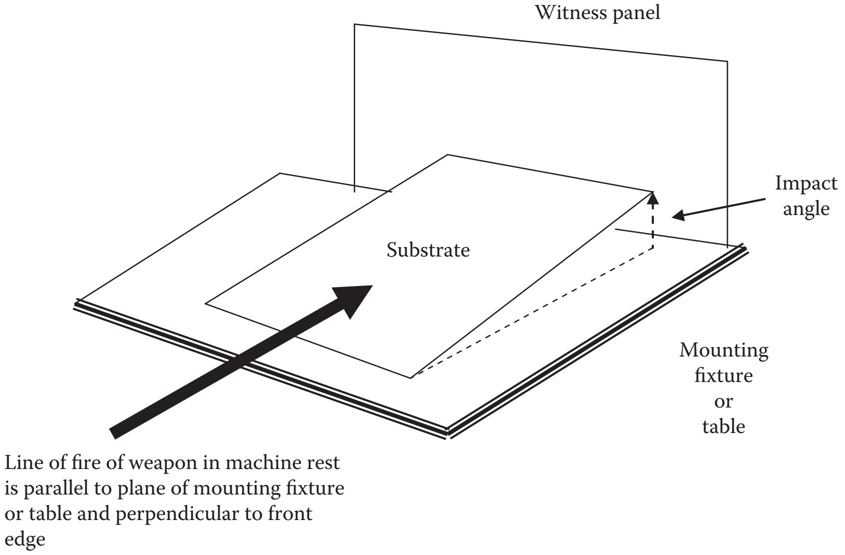

Witness panel
Impact angle
Substrate
Mounting fixture or table
Line of fire of weapon in machine rest is parallel to plane of mounting fixture or table and perpendicular to front edge

Figure 13.23 Critical angle determination.

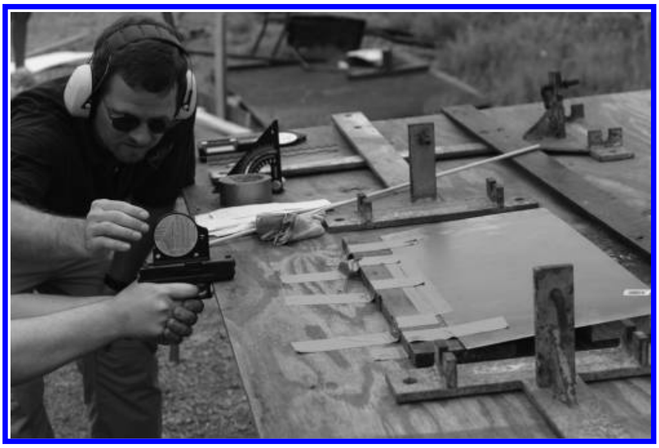


Figure 13.24 Critical angle determination.

and shown in Figure 13.24. The substrate is adjusted to the desired angle by placing blocks or shims under one end. The line of fire is perpendicular to the front edge of the substrate and parallel to the plane of the fixture or table used to hold the substrate.

An initial setting of the angle of impact is tried. If the bullet ricochets, the angle of impact is increased until penetration occurs. If the first shot results in bullet penetration, the angle of impact is decreased until ricochet occurs. Once an angle has been established that reliably produces ricochets, the critical angle has been ascertained.

Establishing Ricochet Angles

By definition, the ricochet angle is the interior angle between the axis of the departing bullet and the substrate. This angle may be simply determined by placing a witness target or panel behind the substrate that produces ricochet. The height of the hole produced in the witness panel above the plane of the substrate forms one of the legs of an imaginary triangle that is used to determine the angle of ricochet. This is illustrated in Figure 13.25.

As an example, suppose we wish to determine the ricochet angle of a Federal .38 Special round-nose lead bullet off a 1/4-inch steel plate when fired from a Smith & Wesson model

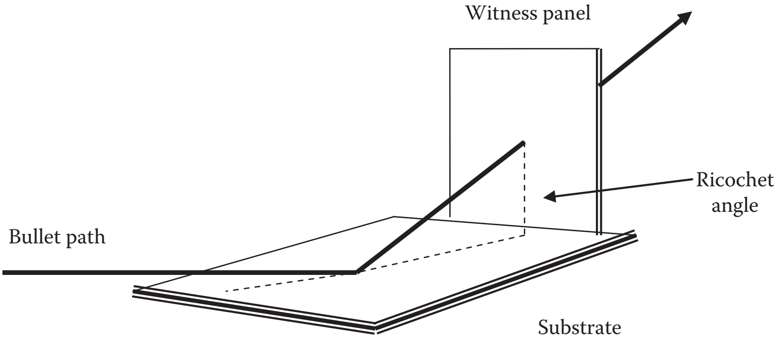
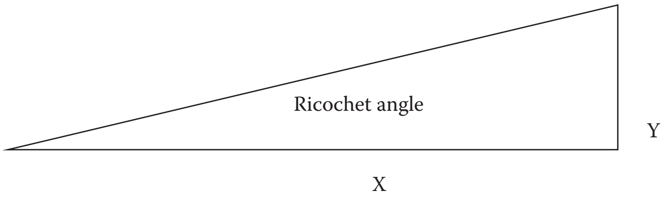


Figure 13.25 Ricochet angle setup.

36 revolver at an impact angle of approximately 10°. We would set up the steel plate on a suitable table at the shooting range along with the weapon in a Ransom Rest mounted on a rotatable table that would allow us to adjust the axis of the bore of the weapon to 10° (this can be measured using an angle gauge).

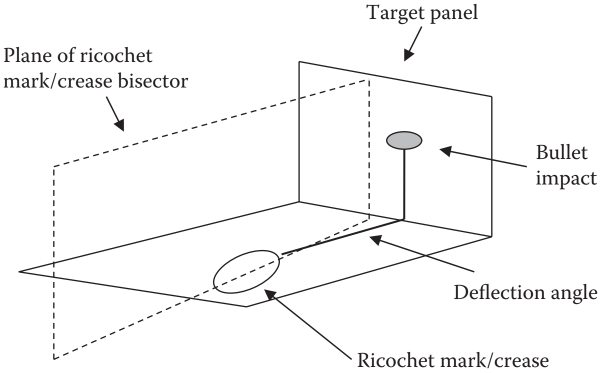
We use a piece of cardboard as a witness panel and place it perpendicular to the steel plate. We fire a series of three shots, replacing our target (witness panel) each time. We then measure the height of each of the three holes produced in the witness panels above the plane of the steel plate. By measuring the distance from the ricochet crease to the witness panel, we have the second leg of the right triangle we will use to determine the ricochet angle. This is shown below.



X = distance from end of ricochet mark/crease to target panel
Y = height above plane of substrate to hole in target panel
Ricochet angle - arctan of X/Y

Establishing Deflection Angles

The deflection angle is the lateral deflection of the bullet trajectory axis upon ricochet. This deflection will be either to the left or the right depending on bullet rotational direction. This general directional determination is typically all that can be reliably determined in terms of deflection. If, for some reason, it would be desired to determine the deflection angle, the same type of setup used for ricochet angle determination could be used. A bisecting line would be drawn through the ricochet mark/crease. The intersection of the plane of the target panel with the perpendicular plane containing the bullet ricochet bisector allows determination (measurement) of the angle of deflection. This is illustrated below.



Establishing Shooter Position

To establish shooter position for a ricochet mark/crease, it is necessary to be able to determine the angle of impact. When the ricochet mark/crease is fairly uniform in shape, the calculation of the angle of impact can be made based on the length and width of the ricochet mark/crease according to the relationship

$$\text{Angle of Impact} = \text{arc sin width/length}$$

If the ricochet mark/crease is asymmetrical, a "best-fit" oval can be approximated, but the results obtained will be affected accordingly. As always, test firing to duplicate the questioned evidence is highly desirable and provides the most reliable results.

Once an angle of impact has been approximated for a ricochet mark/crease, the shooter's height, dominant hand, and weapon position must all be considered in establishing an approximate shooter position. When no information is available to the contrary, the assumption that the shooter used their dominant hand to pull the trigger and held the weapon in a "typical" position must be made. Appropriate caveats must be included in all associated opinions formed.

The use of a scale drawing and/or reenactment simplifies the determination of approximate shooter position. In the case of reenactment, appropriate documentation in the form of photographs and videotaping should be included. As always, it is incumbent upon the investigator to consider all possible positions rather than just the one that happens to fit a particular theory. In most cases, some positions will be more probable than others.

Documentation

In summary, it is possible, by recognizing various indicators, to reliably establish bullet directionality from the resultant ricochet marks and creases. It may be additionally possible to determine general rifling characteristics from the same ricochet marks/creases.

Proper documentation of bullet ricochet marks/creases consists of both taking photographs and making casts. Casts of ricochet creases/marks should be submitted to a qualified firearm examiner for comparison with similar casts of the interior surfaces of the barrels of suspect weapons.

It must be emphasized that the various phenomena presented in this chapter are merely possibilities that should be looked for. It can never be assumed that any or all of the various indicators will always be present. The specific appearance of bullet creases/marks will always be dependent on a number of variables including bullet design/composition, substrate texture/hardness/composition, angle of impact, critical angle, and bullet impact velocity.

Evidence That a Ricochet Has Occurred

There are several things that the field investigator should be on the lookout for as evidence that a ricochet was involved. The first of these is a bullet with a flat side. Bullets frequently

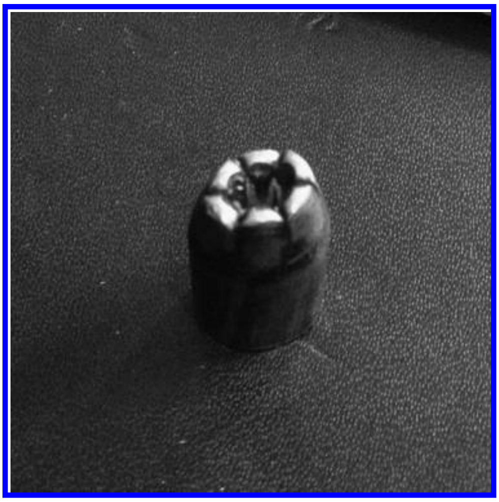


Figure 13.26 Bullet with distorted (flattened) nose indicative of ricochet.

are found lying on the floor or the ground at crime scenes. The bullet should be inspected for any evidence of flattening indicative of a ricochet.

Trace evidence consistent with a particular substrate may be found on bullet surfaces. This material may provide the identity of the substrate that produced the ricochet. Examples include wood, paint, sheet rock, and asphalt.

Irregular wounds and bullet holes are another indicator of possible ricocheting bullets. Flattened, destabilized ricocheting bullets will produce irregular wounds in bodies and irregular bullet holes in inanimate objects. When these are apparent, the investigator should consider the possible responsibility of a ricochet (Figure 13.26).

A bullet with a flattened nose, when found at a shooting scene, should prompt an investigator to search for a bullet ricochet crease or mark.

Case Study

A 66-year-old man and his sister had shared a home (Figure 13.27) in the northeast for a couple of years before deciding to sell and both move back to their original hometown in an adjoining state. According to the man, he and his sister had a heated argument during the midst of packing, causing him to go for a drive to "let things cool down."

He claimed that, on his return, he found that his sister had apparently been shot by an intruder. Her body was located on the floor in her bedroom. She had been shot in the chest and the top of the head. There was an apparent ricochet crease in the wood floor between her body and a chest of drawers (Figure 13.28).

Further examination of the scene revealed a somewhat irregular-shaped hole in the wall, just above the baseboard heater, beyond the body. The irregular shape was indicative of a destabilized/distorted bullet consistent with a ricochet (Figure 13.29). Upon cutting the outer wallboard away, scene investigators observed the bullet impact mark shown in Figure 13.30. That impact mark clearly shows the bullet was traveling sideways. It was clear that the woman had been shot as she lay on the floor with the shot to the top of the

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Figure 13.27 Residence.

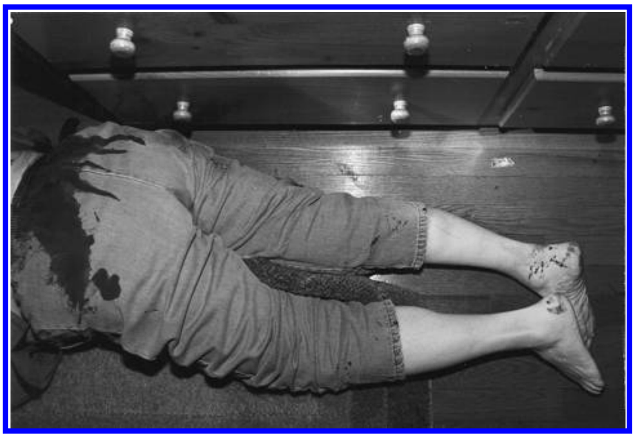

Figure 13.28 **(See color insert.)** Ricochet crease in wood floor (between right calf and chest of drawers).

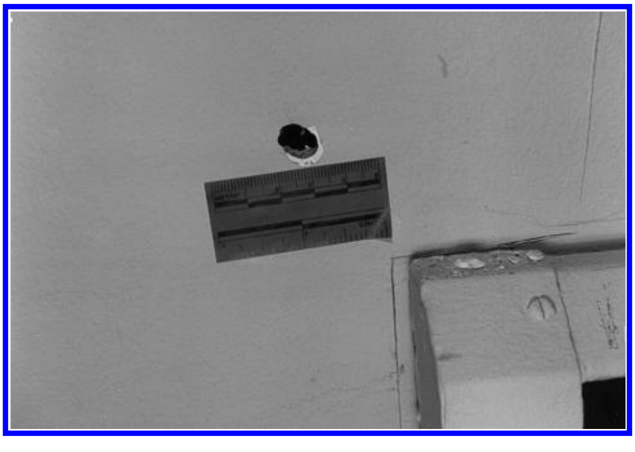

Figure 13.29 Irregular entry hole in wall above baseboard heater.

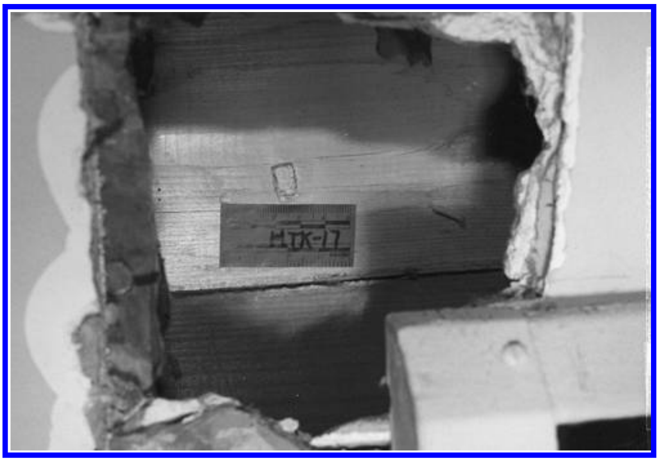

Figure 13.30 Secondary impact to inside surface of outer wall.

head probably coming after the first shot that missed, ricocheted off the floor, and passed through the wall just above the baseboard heater.

Exercises

1. For each of the following ricochet mark/crease images (Figures 13.31–35), you are to determine the directionality (right to left or left to right) and indicate what specific markers of directionality you used to arrive at that determination.
   Answers: Figure 13.31, r to l; Figure 13.32, l to r; Figure 13.33, l to r; Figure 13.34, l to r; Figure 13.35, l to r
2. Which of the above Civil War era fired bullets likely ricocheted (Figure 13.36)?
   Answer: The two deformed bullets on the upper left.
3. A bullet ricochets off the hood of a police patrol vehicle. It is desired to determine the directionality of the bullet that produced the ricochet. An examination of the ricochet crease fails to reveal any indicators of directionality. Is there anything else the investigator can do?

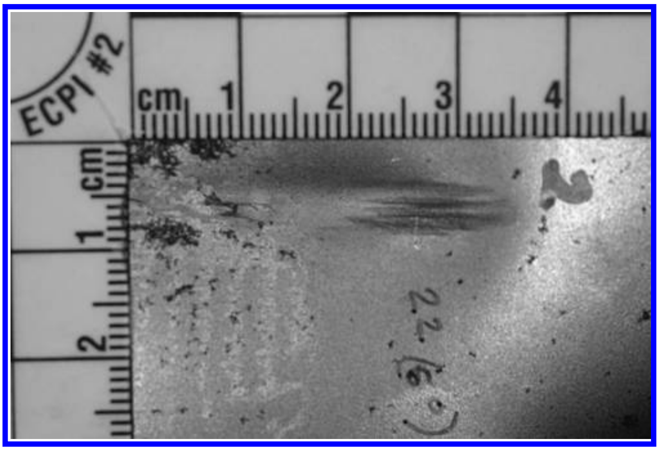

Figure 13.31 Ricochet mark/crease.

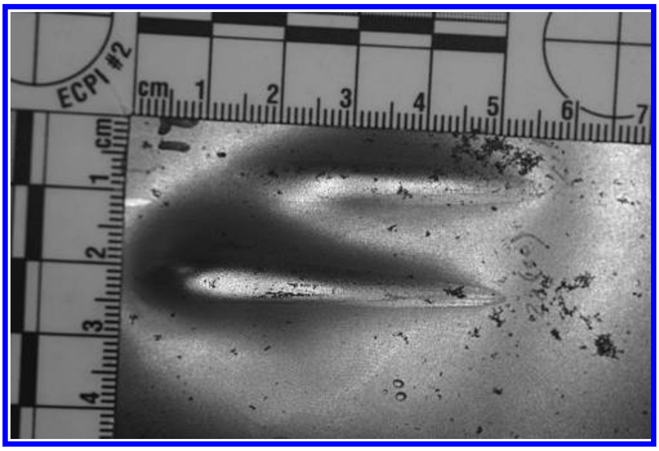

Figure 13.32 Ricochet mark/crease.

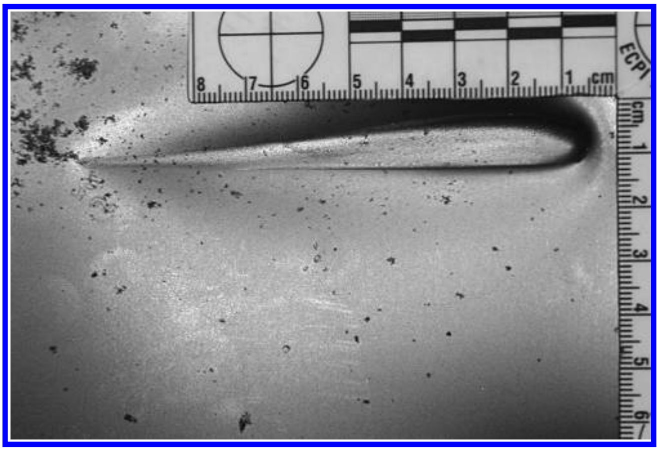

Figure 13.33 Ricochet mark/crease.

Answer: The investigator should attempt to look at the underside of the ricochet crease in the hope of finding the "Christmas tree" effect and, thus, determine the directionality of the shot ("down the tree").

4. An investigator locates an apparent ricochet pattern on smooth concrete produced by a shotgun firing 00 buckshot. The individual pellet ricochet marks are all teardrop shaped and more or less symmetrical. Why is this? Can directionality be established?

   Answer: Since the buckshot is spherical and has no left or right rotation, the resultant ricochet mark should be symmetrical. Directionality may be established by carefully examining for signs of initial impact in the form of heavier lead deposits at one end.

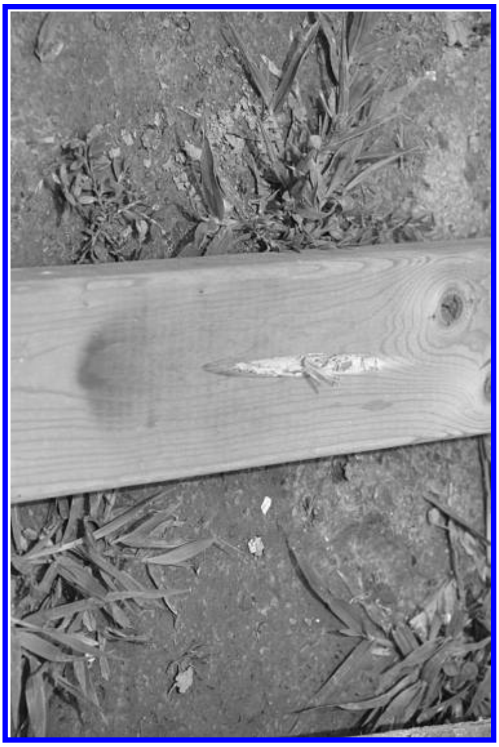

Figure 13.34 Ricochet mark/crease.

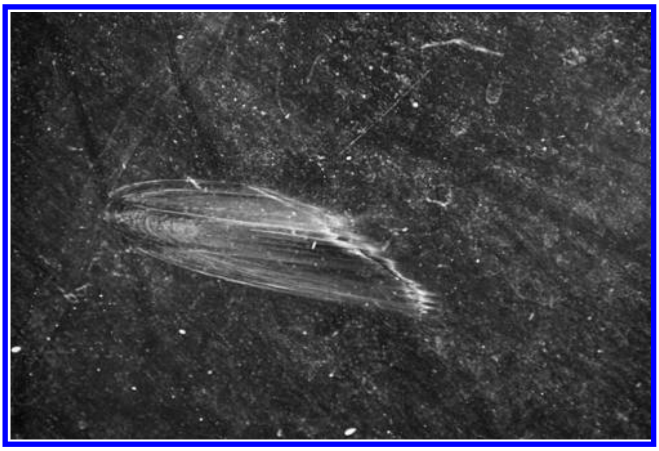

Figure 13.35 Ricochet mark/crease.

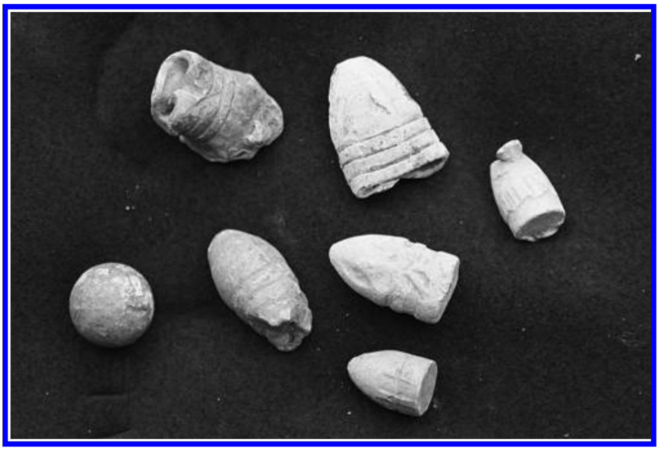

Figure 13.36 Civil War era fired bullets.

5. A ricochet mark on a section of hardwood flooring is observed to be symmetrical in shape. The length of the long axis is found to be 51 mm and the length of the short axis is found to be 11 mm. What was the approximate angle of impact for the bullet that ricocheted?

   Answer: Angle of impact = arc sin of width/length = arc sin of 11/51 = 12°
6. The image shown in Figure 13.37 is the result of an internal ricochet (i.e., this is a view at the side opposite of the ricochet). What was the direction of bullet travel?

   Answer: Right to left.
7. What do you suppose produced the starburst fracture in the plate glass shown in Figure 13.38?

   Answer: This was actually the result of a ricochet off the glass.

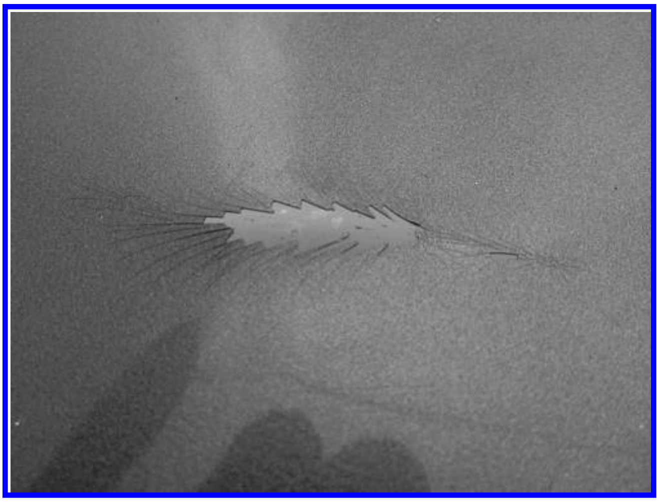

Figure 13.37 Internal ricochet.

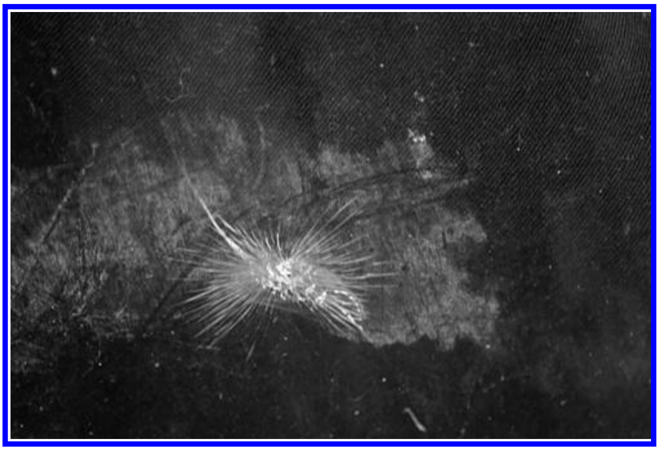

Figure 13.38 Starburst fracture in the plate glass.

8. What direction was the bullet traveling that ricocheted off the “engineered” (i.e., fake) wood tile (Figure 13.39)?

   Answer: r to l (note the missing top layer to the right—that indicates the force is left to right).
9. What direction was the bullet traveling for this ricochet (Figure 13.40)?

   Answer: r to l (with left twist).
10. What direction was the bullet traveling that produced the ricochet mark shown (Figure 13.41)?

    Answer: r to l (with left twist).

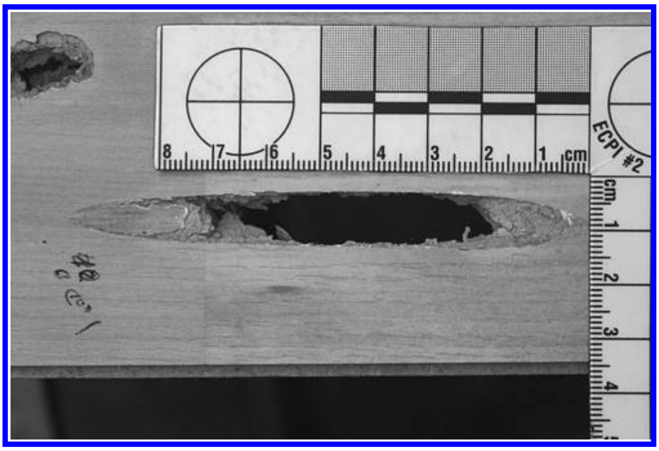

Figure 13.39 Ricochet mark indicating a bullet traveling that ricocheted off the “engineered” (i.e., fake) wood tile.

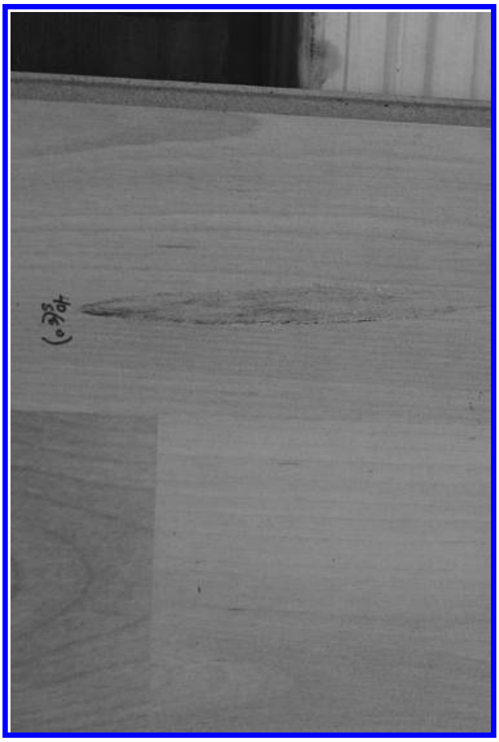

Figure 13.40 Ricochet mark.

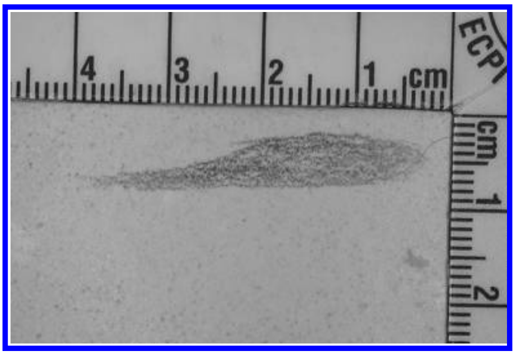

Figure 13.41 Ricochet mark.

Suggested Readings

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Bloodstains and Blood Spatter at Shooting Scenes

14

An anticipated consequence of a shooting incident is the likely shedding of blood. Blood produced by bullets penetrating/perforating human targets is categorized as impact spatter (Figure 14.1). When a bullet enters the body, kinetic energy transfers from the bullet to the body. That energy produces tiny drops of blood termed spatter (see Appendix C). When there is a penetrating injury only (the bullet enters but does not exit), any resultant blood spatter is termed back spatter. Figures 14.2 and 14.3 illustrate back spatter that may be produced.

When there is a perforating gunshot wound (bullet enters AND exits), there will be potential for forward spatter as well as back spatter. Forward spatter is typically of much greater volume than back spatter. A comparison of the two is shown in Figures 14.4 and 14.5.

The presence of overlying clothing, hats, hair, etc., can reduce or eliminate either or both types of spatter produced by bullets. The investigator must be careful not to confuse other spatter-producing events that closely mimic impact spatter from gunshots, as will be discussed in a later section in this chapter (i.e., fly specks, expirated blood, and blood dripping into blood).

Blood Characteristics and Drop Formation

Bloodshed is an expected consequence of a shooting as already stated. Exactly where the resultant bloodstains wind up and what their sizes and shapes are can provide useful information as to the events of the shooting. In order to be able to properly assess the bloodstain evidence associated with a shooting incident, the investigator needs to have at least a basic understanding of bloodstain pattern analysis so that appropriate documentation can be done. This provides the means for someone with the appropriate training and experience to be able to evaluate the evidence. Ideally, someone with that expertise will be present at the shooting scene to make first-hand evaluations.

Some basic facts that all criminal investigators should know about blood include the following:

- The average adult human body contains 5–6 liters of blood.
- Blood consists of a combination of solids and liquid with dissolved gases.
- The liquid portion of blood is called plasma and makes up about 55% of the volume.
- The solid portion includes red cells, white cells, and platelets.
- Red cells transport oxygen via hemoglobin.
- White cells fight infection.
- Platelets form clots to stop blood loss from breached veins and arteries.

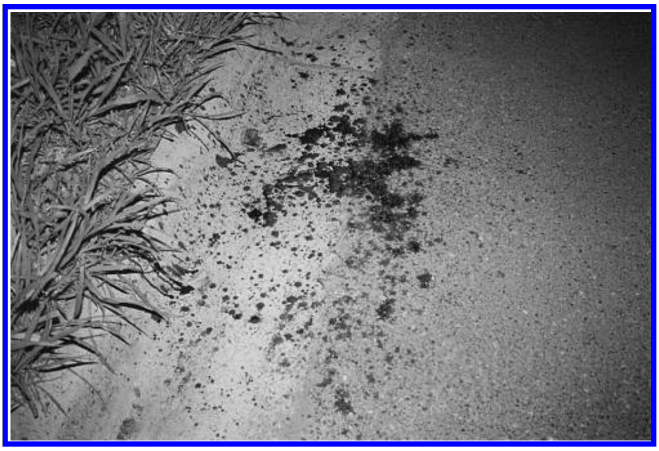


Figure 14.1 Bloodstains at a shooting scene.

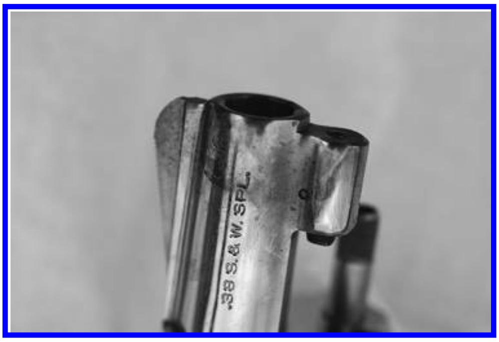


Figure 14.2 Back spatter produced by a near contact shot.

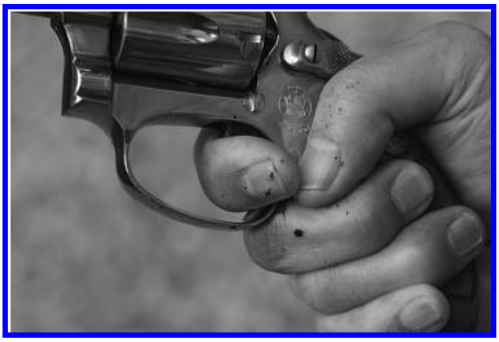


Figure 14.3 Blood on gun and hand (back spatter).

- When the solids separate from the liquid, the liquid is referred to as serum (this takes place over time for blood outside the body) (Figure 14.6).
- Blood is red because of the red cells and the presence of oxygen molecules.
- Blood darkens as it ages and loses oxygen (Figure 14.7).
- Blood is about six times as viscous as water.
- Blood drops are spherical in flight (actually oscillating spheres).

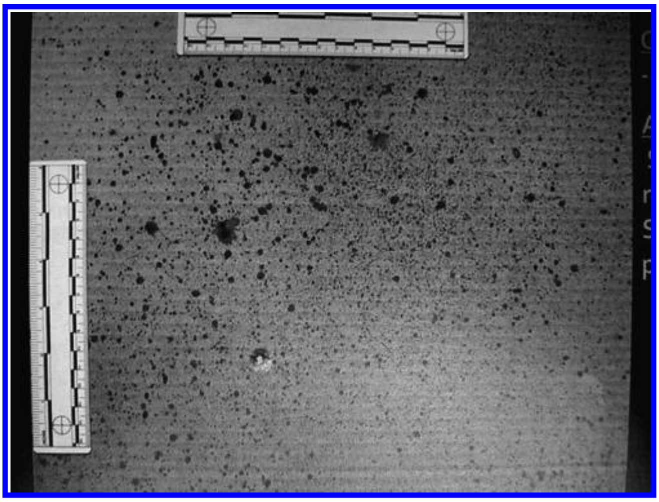


Figure 14.4 Forward spatter.

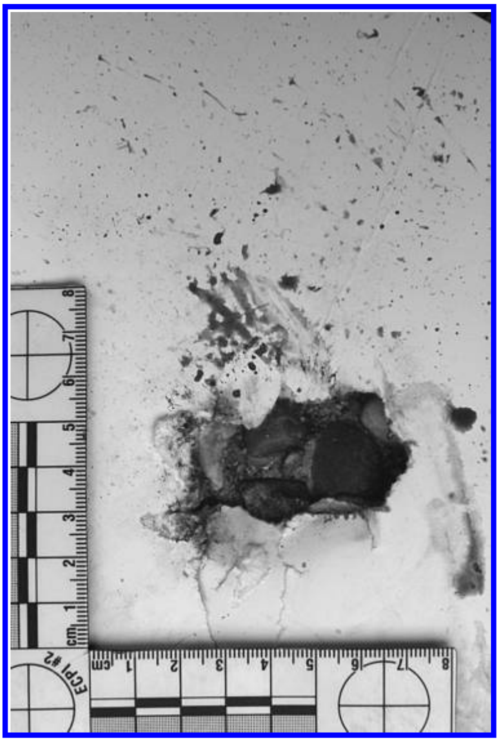


Figure 14.5 Back spatter (shot was fired through hole in panel at contact distance).

- Blood striking a surface at approximately 90° produces circular stains (the smoother the surface, the smoother the stain edges) (Figure 14.8a and b).
- Blood striking a surface at less than 90° produces elongated stains (Figure 14.9).
- Bloodstain direction of travel is indicated by the shape of the stain (the direction of travel is from the large end toward the small or irregular end).

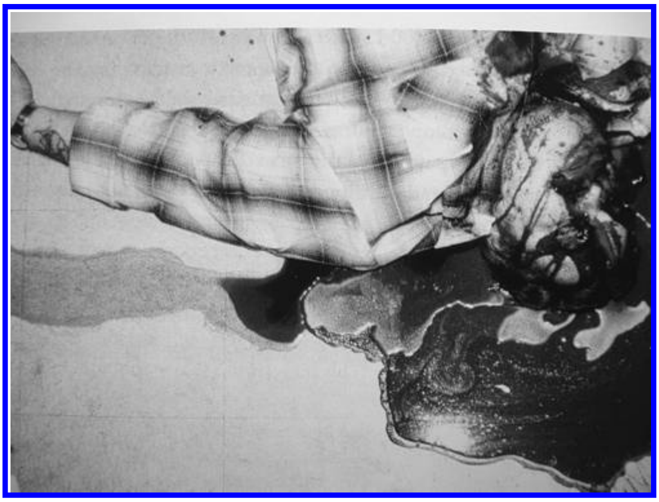


Figure 14.6 Serum separation.

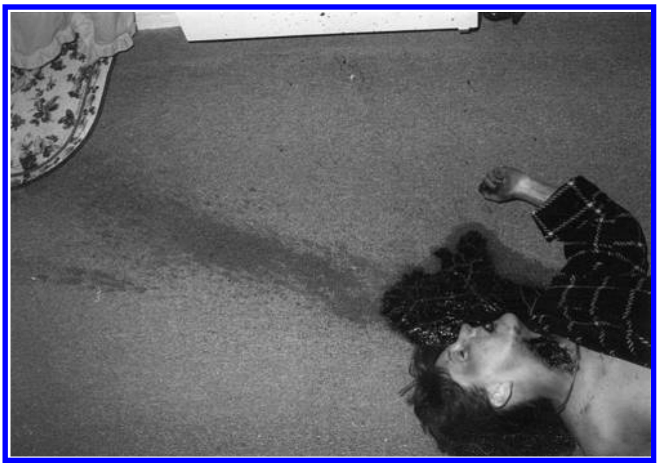
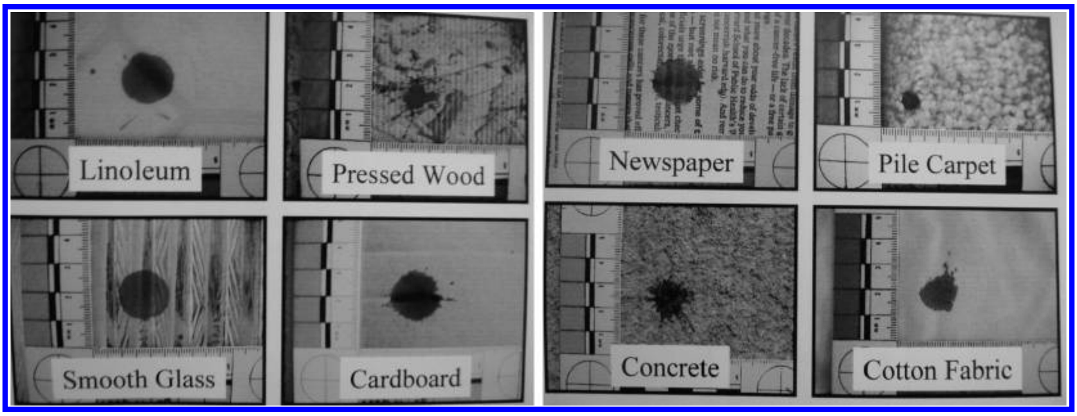


Figure 14.7 Aged blood that has blackened.


Linoleum
Pressed Wood
Smooth Glass
Cardboard
Newspaper
Pile Carpet
Concrete
Cotton Fabric

(a) (b)

Figure 14.8 (a, b) Surface effects.

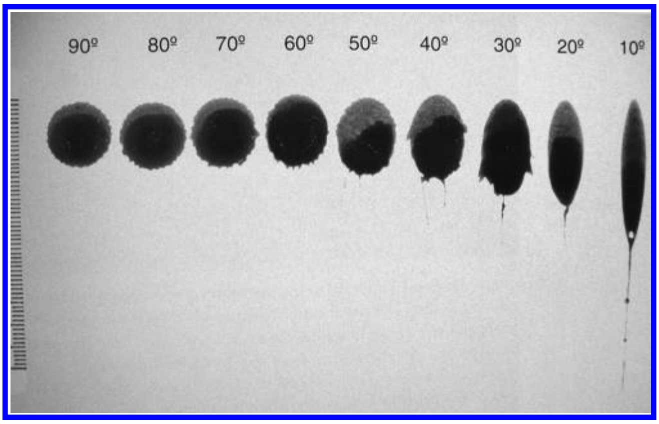


Figure 14.9 Impact angle and stain shape.

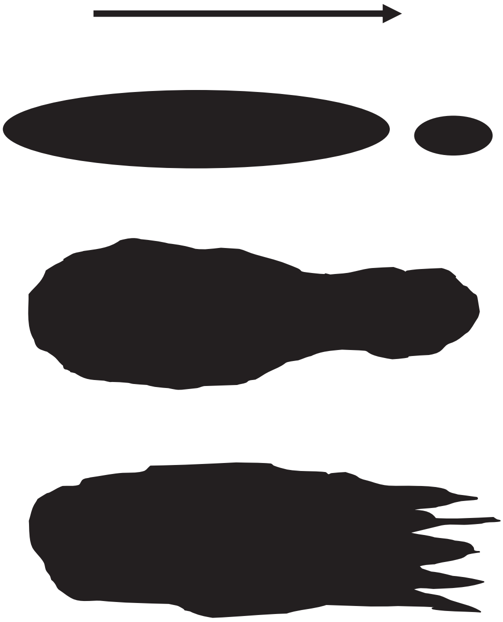


Figure 14.10 Three basic bloodstain shapes.

- There are three general shapes for stains resulting from impact at less than 90° (see Figure 14.10), depending largely on the substrate surface texture velocity and angle of impact.
- The angle of impact for a bloodstain is equal to the arc sin of stain width divided by stain length (impact angle [IA] = arc sin width/length) (Figures 14.11 and 14.12).

It should be recalled by the reader that the angle of impact calculation for a bullet hole or ricochet mark/crease is calculated the same way as the angle of impact of a bloodstain. As with bullet holes and ricochet marks/creases, less than symmetrical bloodstains must be approximated as to the "best-fit oval."

Thus far, in this text we have stressed the importance of experimentation and testing for final confirmation of the theories we develop in shooting incident analyses and

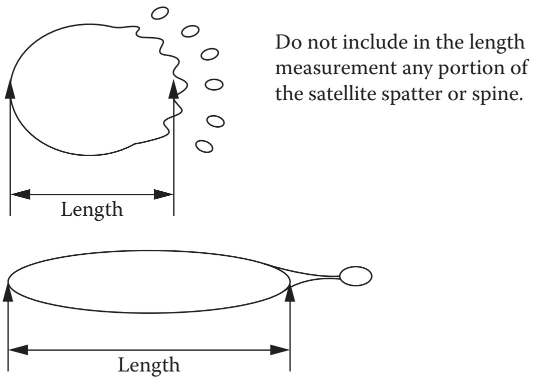

Do not include in the length measurement any portion of the satellite spatter or spine.
Length
Length

Figure 14.11 Stain length measurement.

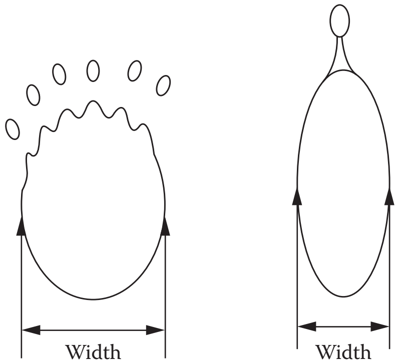

Width
Width

Figure 14.12 Stain width measurement.

reconstruction. In that context, we have stressed the importance of duplicating the circumstances involved as closely as possible. This is particularly true in the case of blood because of its unique properties. It simply will not work to substitute water with red food coloring for blood, for example, in a test where the behavior of blood is involved. This is apparent when we compare some of the physical characteristics of blood with those of water.

Water

- Density—1.0 g/ml at 4°C
- Specific gravity—1.00
- Viscosity—1
- Surface tension—72.5 dynes/cm

Blood

- Density—1.1 g/ml at 4°C
- Specific gravity—1.06
- Viscosity—6
- Surface tension—50 dynes/cm

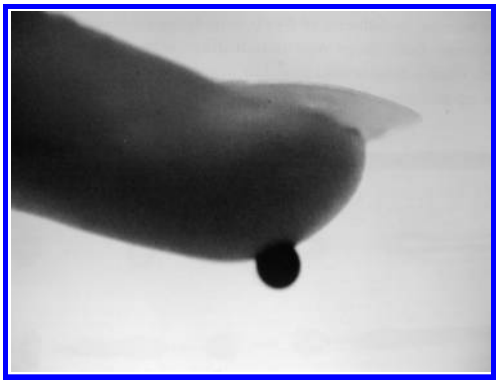


Figure 14.13 Adhesive force—blood on finger.

There are obviously significant differences between the viscosities and the surface tensions of water as compared to blood. The intermolecular forces of attraction involved for the various components of blood account for these differences. The old saying "Blood runs thicker than water" clearly has a scientific basis. Viscosity is directly related to liquid flow rates. The greater viscosity of blood means it will flow at a much slower rate than water.

In order for a drop of blood to form, gravity must overcome the surface tension that holds the blood together in one mass as well as the force of attraction between the blood and the surface it is on (Figure 14.13). In effect, this means a drop will form and break away whenever its weight is sufficient to overcome the forces of attraction that tend to hold it together. This can be aided by external forces such as shaking, slinging, or an abrupt halt in the swing of a blood-covered object.

In terms of drop formation as a result of impact to a blood source, the greater the force, the smaller the size of the blood drop that will be produced. From a mathematical perspective, this is an inverse relationship. Accordingly, a small force imparted to a blood source, such as stepping into a blood pool, produces relatively large bloodstains.

With regard to distance of travel for blood spatter, the smaller the size, the shorter the distance of travel from the source (this is a direct relationship as opposed to an inverse relationship). A good way to present this concept to a jury is to make an analogy to a garden hose with an adjustable spray nozzle. Most people are readily aware that the fine mist adjustment of the spray nozzle will not project water nearly as far as a coarse or stream setting. The reason, of course, is that the larger volume drops have more mass and, subsequently, more momentum with which to resist gravity and air friction. Hence, they are able to travel farther from their source in any direction.

Blood Spatter Associated with Firearms Injuries

Before we go any further, let us get the terminology straight (again, the reader should consult the SWGSTAIN Glossary in Appendix C). The result of a force acting on some blood source is termed spatter. This term is frequently erroneously used interchangeably with the term splatter. Perhaps the best distinction that can be made between the two terms is to point out that spatter is a noun and splatter is a verb. Spatter is the result of the action or force.

The mechanisms acting on blood sources that produce spatter are generally categorized as impact mechanisms, projection mechanisms, and secondary mechanisms. Impact mechanisms include gunshots, beatings/stabbings, and power tools. Differences in stain shapes and sizes can sometimes help distinguish between responsible mechanisms, but at face value alone this can be risky. Not finding impact spatter to be present can be attributable to a number of reasons. The presence of heavy clothing, hair, or other intervening objects can prevent its deposition on objects in proximity to the victim. The tiny droplets can simply be indistinguishable when they fall on dark objects. They can be hidden in the fibers of deep pile carpet or on debris-covered floors or the ground. Two examples of impact spatter are seen in Figures 14.14 and 14.15.

When impact spatter is deposited on someone or something as a result of a gunshot, it is typical to also find larger size stains that do not fit the accepted criteria for spatter from a gunshot. This can be disconcerting to the investigator who is not experienced in

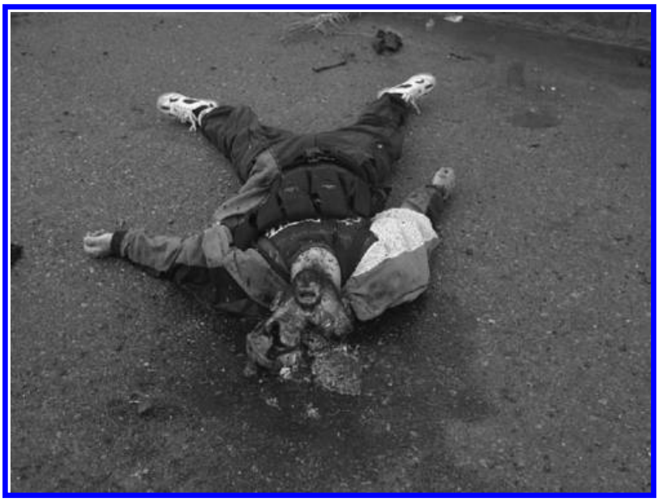


Figure 14.14 **(See color insert.)** Head shot to a suicide bomber.

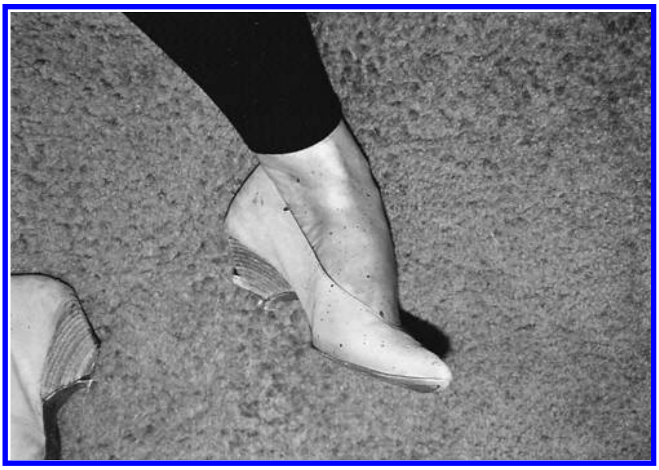


Figure 14.15 Impact spatter from a beating.

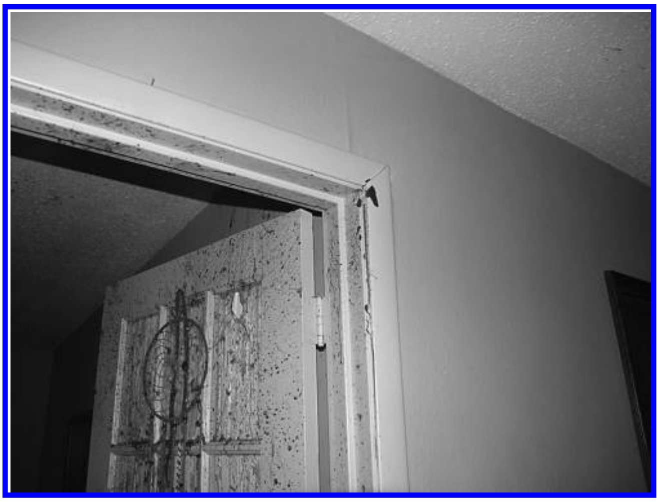


Figure 14.16 Bloodstain resulting from a large caliber handgun fired into the victim's head at contact distance.

bloodstain pattern analysis. What must be kept in mind is that secondary spatter that is greater in size will frequently also be present as a result of the forces of bullets, combustion gases, and the presence of preexisting wounds. The determining factor with regard to designating a particular stain as being from a gunshot begins with establishing that a gunshot was involved, as simplistic as that may sound. Next is to determine whether the preponderance of the individual stains has a small diameter (i.e., 1 mm or less). A pattern with multiple sized stains produced by a gunshot is shown in Figure 14.16.

Figure 14.2 shows back spatter on the barrel of a revolver produced by a near-contact shot. It can be seen in that figure that the bloodstain has a mist-like appearance. There are four sources that may produce the aerosol mist as well as larger sized stains, bits of tissue, and skin. These include

- Entrance wounds
- Exit wounds
- Preexisting bloody wounds
- Muzzle blast within close proximity to a blood source

As a point of clarification, many stains are produced as a result of blood striking a surface at less than 90°, in which case an elongated stain results. Accordingly, it is the stain width or short axis that would be comparable to diameter.

As already discussed, impact spatter from a gunshot often presents itself as a combination of stain diameters, the majority of which will be 1 mm or less. Both back spatter and forward spatter will have a conical distribution from their source. The size of this conical distribution tends to be greater for forward spatter emanating from the exit wound. This is because the force is directed along that same path. This effect is enhanced when the exit wound is larger than the entry wound. This is illustrated in Figure 14.17.

Some obvious contradictions to the proposed model for back spatter/forward spatter production exist. Close-range shots from high-power rifles and shotguns, for example, produce large, excavating entrance wounds that result in large amounts of tissue, skin,

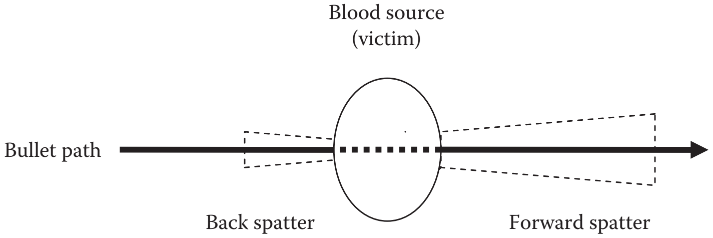


Figure 14.17 Forward and back spatter.

bone, and blood drops of all sizes being directed back toward the shooter. The small entrance wound, large exit wound theory depends on the location of the body and the weapon used. A rifle fired at close range into the abdominal area, for example, can exhibit a large entrance wound but a small exit wound.

Blood on/in Weapons

The combustion gases from discharge may aid in the production of the aerosol mist that typifies gunshot-produced spatter. This is particularly true for contact shots to the head where the gases collect between the skull and the scalp before erupting back toward the muzzle of the gun (the path of least resistance). It is not unusual for blood to be deposited on/in weapons under these conditions.

In experimental work done by the author concerning this phenomenon, a number of .38 special revolvers having barrel lengths ranging from 2 to 6 inches were test fired into blood-soaked sponges to determine the likelihood for blood deposition at various muzzle-to-target distances. The results of this limited study indicated that barrel length was of no particular importance with regard to blood deposition in/on the weapons tested. Muzzle-to-target distance, as expected, was the controlling factor as to whether blood deposition occurred. Finding blood inside the bore or on the exterior surfaces of the guns tested was found to be limited to contact or near-contact distances.

As a standard practice in firearm examinations related to shooting incident reconstruction it is highly recommended that weapons be carefully examined for the presence of blood in the bores and on exterior surfaces. A gun cleaning patch should be run through the bore (and each of the chambers of revolvers) and then examined/tested for blood. Vincent Di Maio, in his text *Gunshot Wounds*, noted that blood in the bore of weapons can survive one or even two test firings. Accordingly, test firing should not preclude bore examination ("One test equals 1000 excuses").

The examination of the bore may be carried out using a bore scope. Bore scopes use tiny mirrors at the end of small diameter steel tubes to allow inspection of the interior surfaces of barrels without disturbing any potential evidence. This further allows images to be recorded before removal of any suspected bloodstains by interfacing digital cameras. This is clearly a superior method for documenting the presence of blood as compared to simply reporting finding blood on a swab passed through the bore. On the other hand, not bothering to check for blood at all is the unpardonable sin.

Blood on the Hands of the Shooter

A great deal of significance, particularly by the uninformed, is frequently placed on the lack of high velocity impact spatter (HVIS) on the hands of victims of gunshot wounds to the head where there is a question of homicide versus suicide. In any shooting incident, impact spatter should be looked for, but, as already discussed, not finding it cannot be taken as proof positive of anything more than just that it was not there. In fact, studies have shown that in the majority of known cases of self-inflicted gunshots to the head with hand guns, blood did not show up on the shooter's gun hand. In the case of a shooting incident where blood is found on the weapon and to such an extent that it is inconceivable as to how it would not be also present on the hand holding the gun, some explanation must be found by the investigator. Possible explanations could include cleanup or the presence of gloves.

On the other hand (no pun intended), finding impact spatter on the hands is proof positive that the hand was in reasonable proximity to the source of blood. Once again, the fine aerosol mist of blood associated with a gunshot can be very difficult to see and must be carefully looked for. In the best-case scenario, there will be a wide distribution of blood on the weapon with an obvious void on the handle. Blood spatter on the hand should "fill in the gaps." When the presence of impact spatter is limited to the hand, it should be present on the back of the hand as opposed to the palmer surface. Finding impact spatter on the palm is an indication of something other than gripping and firing a weapon with that hand. This is illustrated in Figures 14.18 and 14.19.

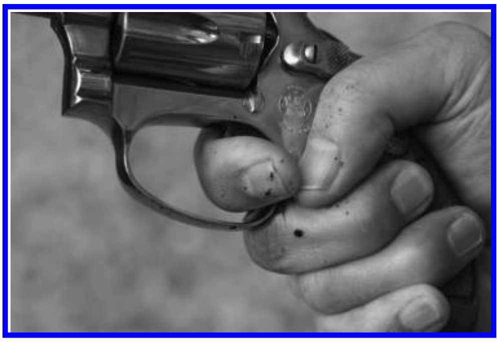


Figure 14.18 Spatter on hand and gun trigger guard.

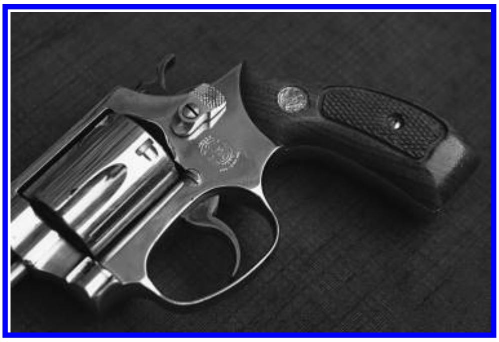


Figure 14.19 No blood spatter on gun grips.

Blood on Objects at the Shooting Scene

It is widely accepted that impact spatter produced by a gunshot can travel no farther than about 6 feet due to gravity and air friction acting on the tiny drops to bring them to ground. Thus, finding impact spatter on a wall in the area of a bullet hole means the victim had to have been within about 6 feet of that wall when shot. Once again, consideration must be given to the presence of persons or things that could prevent the blood from reaching potential targets within the scene.

A common misconception regarding bloodstains at shooting scenes is that such stains are produced whenever a person is shot, and the location of these bloodstains is consistent with the individual's position. Although it is certainly possible for blood to be deposited by a shooting victim at the location in which they were shot, the reasons why this does not always happen abound. First, if the area of the gunshot is covered by articles of clothing, the blood can be absorbed by the clothing. If the individual who is shot remains upright and mobile, it is quite possible that bleeding will be internal only for some period. Thus, finding bloodstains near where a gunshot victim ultimately goes down and dies may not coincide with where they were standing when they were shot.

Blood pools can provide information as to a shooting victim having been at a certain location for whatever length of time would be required for the blood pool to have formed. Exactly how long that might be is usually beyond the expertise of the investigator and falls into the realm of the pathologist. A blood pool that has coagulated and started to dry around the edges is shown in Figure 14.20.

Questions as to whether a shooting victim was standing, kneeling, or otherwise positioned are often posed to the bloodstain pattern analyst. Although these questions can sometimes be answered to one degree or another, the answer must be based on something other than bloodstain diameter versus height above the target. It is well known for falling blood drops that as height above a target increases (up to a maximum distance of 6 or 7 feet), stain diameter increases (Figure 14.21). The problem with using a comparison of stain diameters to attempt to establish height of fall is that the drop volume is unknown and cannot be determined, presuming a given volume is entirely unacceptable.

Suppose we have an individual who was standing upright when shot through the arm. As blood starts to fall to the floor, bloodstains are formed. During the scene investigation,

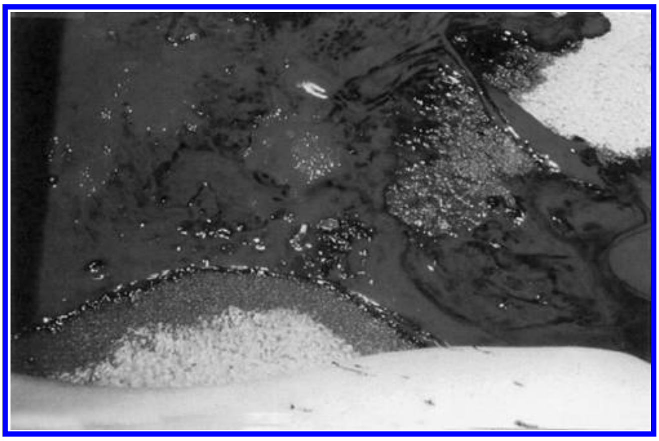


Figure 14.20 **(See color insert.)** Pool of blood that has coagulated and is starting to dry (dark edges).

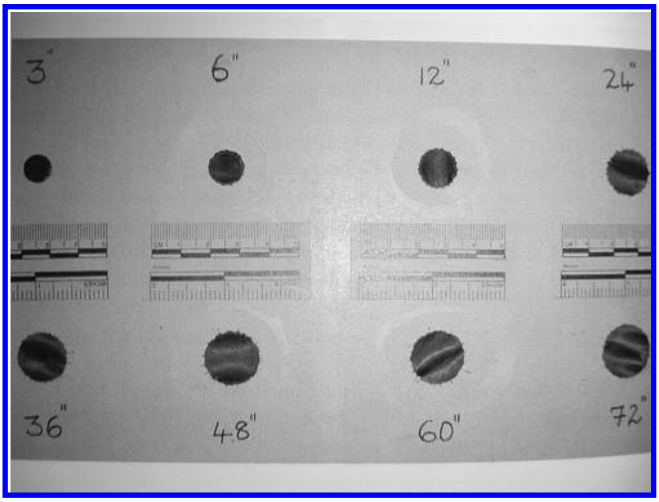


Figure 14.21 Distance versus diameter.

the examiner looks at these bloodstains with an eye toward determining the victim's position (say upright or kneeling). The blood drops resulting from the wound will display differing volumes. This leads to the possibility that a large drop falling from a lower position could have a diameter similar to that of a smaller drop falling from a greater height. It is for this reason that speculation as to height above the ground cannot be given any credence without knowing what the drop volume is and, in the context of a crime scene, drop volume cannot be ascertained.

Nongunshot Dynamics That Can Mimic High-Velocity Impact Blood Spatter

Classifying bloodstain dynamics on the basis of stain diameter alone is risky business. Bloodstain pattern analysts know that as much information as possible is required before rendering an opinion as to the dynamics responsible for a particular pattern. As an extreme example, suppose a bloodstain pattern is observed to consist of mainly stains having diameters less than 1 mm and, on this basis, the investigator declares the pattern to be indicative of a gunshot. Later, it is determined that there was, in fact, no gunshot involved—not a good situation to be in as a crime scene reconstructionist!

As it turns out, there are several nongunshot dynamics that can mimic impact spatter from a gunshot:

1. Blood dripping into blood
2. Expirated blood
3. Fly specks

Blood dripping into blood results in satellite spatters that fall into the range of size of impact spatter. This source of tiny bloodstains may or may not be readily ascertainable. Suppose that an individual was standing beside blood dripping to the floor from a blow struck to a man's head. As each drop hits previously deposited drops, satellite spatters land on the individual's right shoe. Later on, the bloodstains on the shoe are used to place the individual as standing with his foot beside the victim's head as the victim lay on the floor and was shot in the head—an erroneous conclusion resulting from blood dripping into blood mimicking impact spatter. Examples appear in Figures 14.22 and 14.23.

The second nongunshot dynamic that can easily be mistaken for impact spatter from a gunshot is expiratory blood. Whenever the airways (i.e., the nose and/or mouth) have blood present, sneezing, coughing, gurgling, sudden exhalation, and similar actions can produce tiny spatters that mimic HVIS in appearance. Frequently, the presence of air bubbles can be seen in the form of spatters with a "fisheye" appearance. Also, the dilution of the blood with saliva sometimes can be recognized. The investigator can take a sample and have the crime laboratory analyze it for the presence of the enzyme amylase. However, not finding amylase cannot eliminate the possibility of expiratory blood being present. Expirated blood is present on the keyboard in Figure 14.24.

Fly specks result from flies consuming blood from a body and then regurgitating the remains back onto the body. These small, circular stains can easily be mistaken for impact spatter (Figure 14.25). Obviously, fly specks require access to a body by the insects. If no such access is available, it is not possible for this to occur; however, even with indoor scenes, flies sometimes are around.

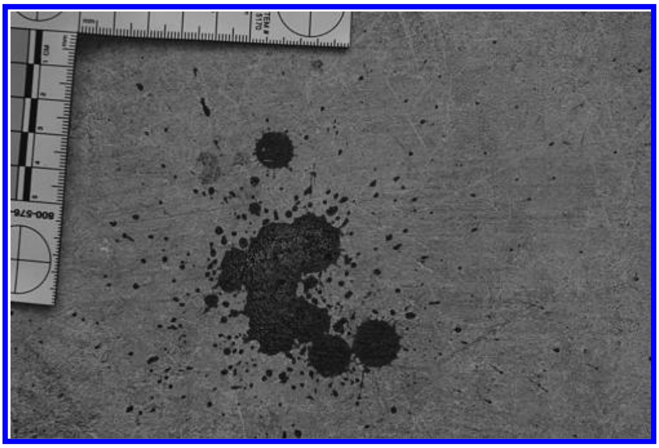


Figure 14.22 Blood dripping into blood.

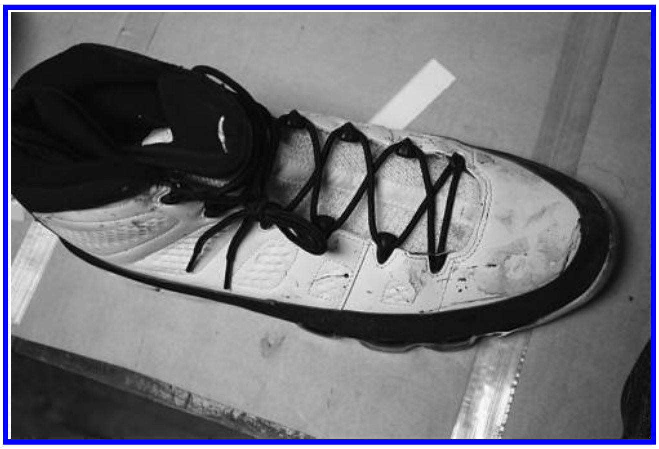


Figure 14.23 Bloodstains on shoe (satellites are from blood dripping into blood).

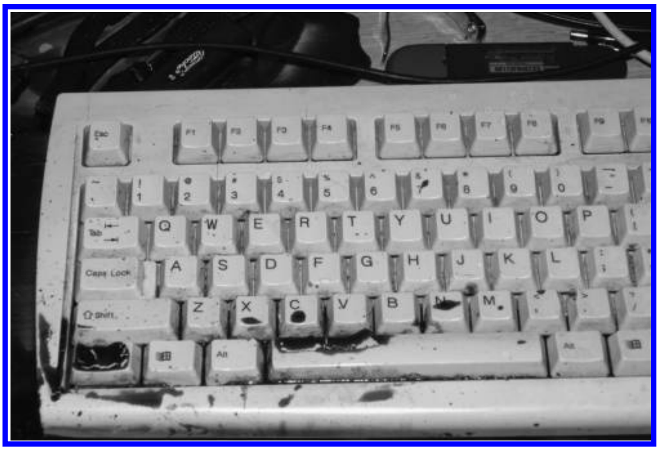


Figure 14.24 Expiratory blood.

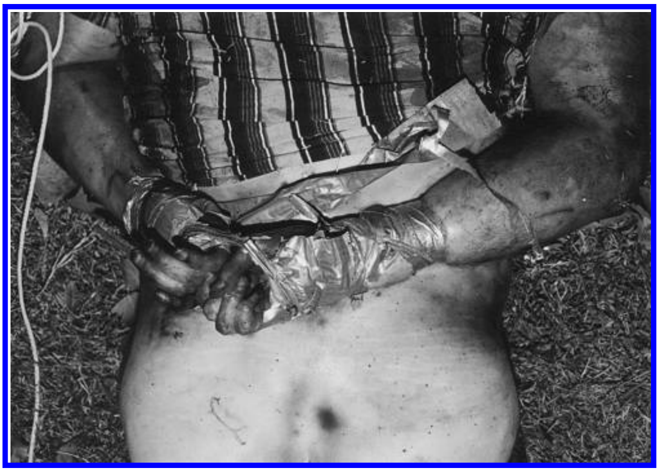


Figure 14.25 Fly specks on the buttocks of a strangulation victim.

In summary, the scene investigator who finds what appears to be impact spatter from a gunshot should first establish that a gunshot was involved in the incident under investigation. That being done, the investigator needs to eliminate the possibility of nongunshot dynamics as being responsible for the observed pattern.

Blood and Its Use in Time Line Development

There are a number of considerations associated with bloodstains and pools of blood at crime scenes that the investigator needs to look for and consider as a time line is developed and the reconstruction proceeds. In order for these considerations to be valid, their presence must be strictly correlated with the time of observation. In other words, using the presence of dried or clotted blood to contradict a defendant's version of events is meaningless unless the time of observance can be reliably established, and it is relevant. Observing clotted blood in a crime scene photograph, for example, may have no significance if the photograph was taken hours after the blood was shed.

There are three considerations involving blood that the investigator should look for and document if observed.

- Dried blood
- Clotted blood
- Lividity

The significance of each of these will be entirely dependent on establishing when they were first observed and how their presence relates to the purported time line represented by victims, witnesses, and/or defendants.

The time for blood to dry depends on a number of factors. The volume of the bloodstain or pool of blood has a considerable effect as does the temperature, humidity, air current, and surface absorption characteristics. In any event, if the first responder to arrive at a shooting scene notes dried bloodstains and blood pools to be present and the blood was supposedly shed within minutes of arrival, further investigation is warranted. Bloodstains and pools dry from outside to inside. That is, an outer crust forms and continues toward the center of the stain or pool over time. In some instances, this will indicate an attempt to clean up bloodstains owing to the presence of rings of dry blood ("skeletonized blood") remaining after the wet center portion was wiped away.

Stain drying time on skin and other surfaces may be less than 5 minutes for small stains but considerably longer for larger stains and pools. If there is a possible contradiction between the time line presented by an involved individual at a scene and the presence of dried blood, testing may be carried out to resolve the issue. The test conditions must duplicate those at the crime scene as nearly as possible.

The presence of blood clots and pools of clotted blood also give the investigator a way of estimating time passage at a scene. The time required for blood to clot varies, but the minimum time required is generally accepted to be in the 6- to 8-minute range. This should not be taken to mean that a large pool of blood can entirely clot within that time frame, only that clotting might begin. As an example, the author acquired 5 gallons of bovine blood from a slaughterhouse for use in a blood spatter class he was teaching. The time from acquisition to arrival back at the author's residence was 40 minutes. When the bucket of bovine blood was examined, it was entirely clotted.

The presence of spattered blood clots is indicative of the passage of time between an initial injury and a secondary attack (blows struck/shots fired subsequent to the initial blood producing event). If an individual was beaten, for example, and then later shot, the shot could produce spattered clots.

Lividity, although clearly within the purview of the forensic pathologist, is something that the investigator should recognize when it presents itself and document appropriately. Lividity is the settling of blood following death. Because of gravity, blood within the body settles at the lowest possible point. Depending on skin tone, lividity manifests itself as a red-purple to simply dark appearance of the skin. The time required for lividity to first appear varies with individuals and environmental conditions. It is generally accepted that lividity takes at least 20 minutes to appear. After 8–10 hours, lividity becomes "fixed." This means that if the body is repositioned after fixation, the original position will be indicated by the persistence of lividity (Figure 14.26).

Based on the location of the lividity, it may be evident that the body has been moved from its original position.

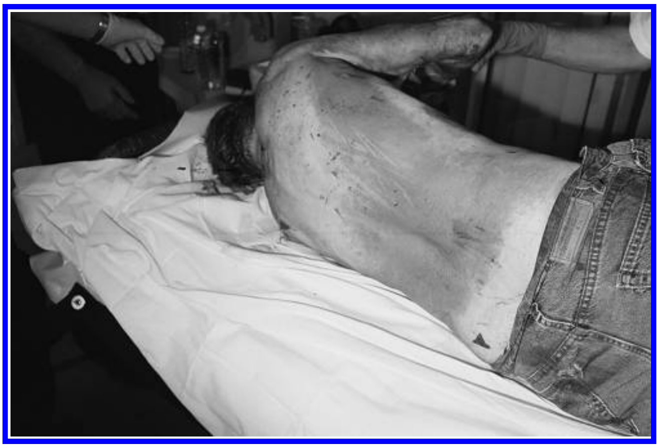


Figure 14.26 Postmortem lividity.

Case Study

Production of Pseudo-Impact Blood Spatter

A man was arrested and charged with murder after the shooting death of his brother in the man's home. According to the man, his brother had been depressed following the death of their parents and, in an unrelated event, an older brother. According to the man, he was seated at a computer table when his brother came in drunk and carrying a large caliber handgun (a .50 caliber Desert Eagle semiautomatic pistol). The man claimed that the brother turned his back on the man, put the muzzle of the gun to the back of his (the brother's) head and pulled the trigger, "blowing his head open." The shooting scene and victim are shown in Figure 14.27.

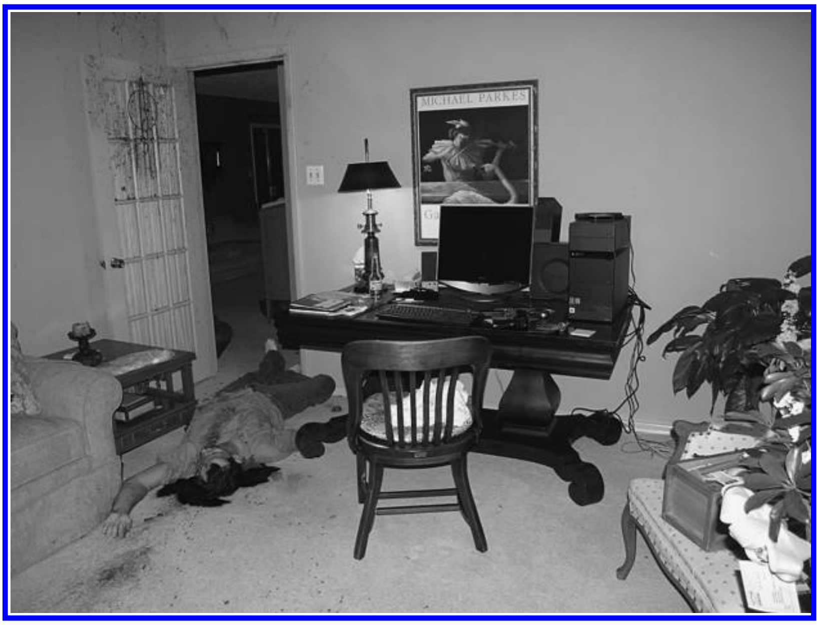


Figure 14.27 Shooting scene.

The man stated that he was “covered” with blood as a result. He further stated that he got up from the chair and pulled his blood soaked white T-shirt off and laid it on the chair before calling police. Apparently, because of the location of the entry wound (contact shot to the back of the head) and the distribution and appearance of tiny bloodstains on the T-shirt, the police did not buy the man’s version of events and filed murder charges against him. The police carried out a reenactment in which they concluded that it was “impossible” for the brother to have shot himself in the back of the head with the large pistol (Figure 14.28).

The response by the defense was to illustrate that by the brother having merely turned his head to the left, the shot was, in fact, possible (Figure 14.29).

The defense also did a reenactment in which the defendant put on the bloody clothing he had worn the night of the shooting and sat down on the chair at the computer table. The prosecution had previously examined the computer table and chair and had marked the locations of bloodstains along the left side of the chair back.

As can be seen in Figures 14.30 and 14.31, all the blood spatter identified by the prosecution is visible with the defendant seated in the chair (note that Figure 14.31 was taken

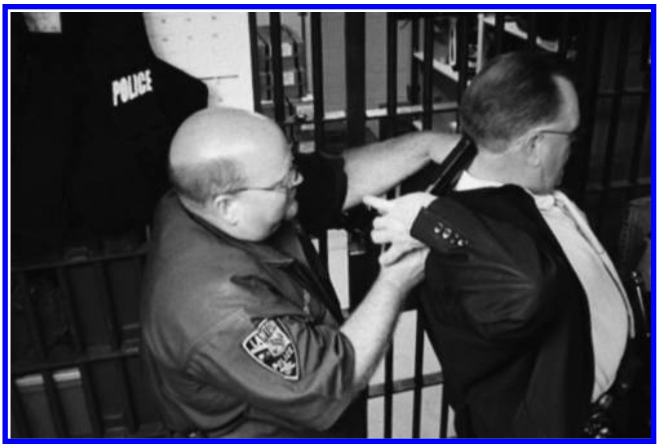


Figure 14.28 Police reenactment.

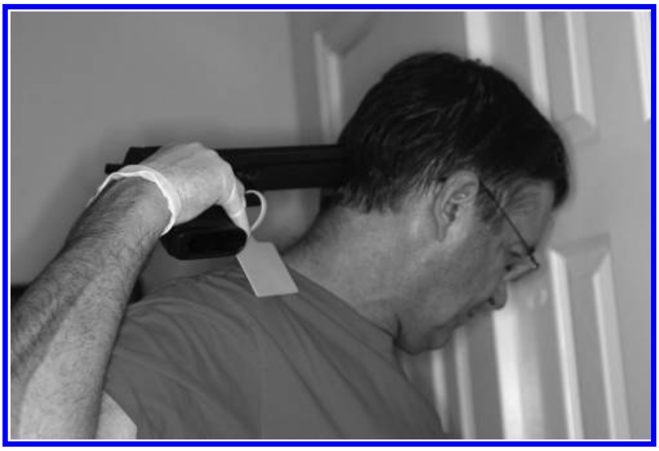


Figure 14.29 Defense reenactment.

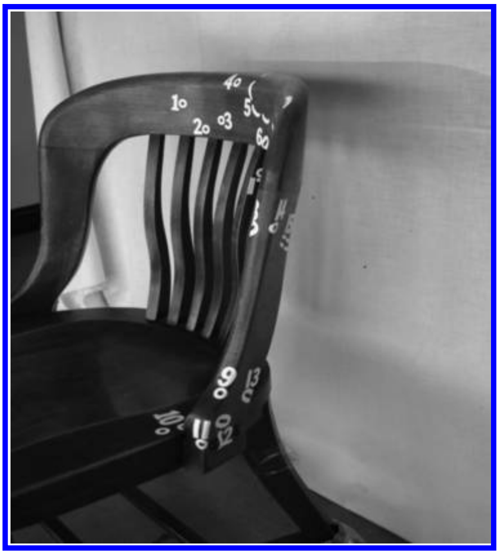


Figure 14.30 Chair the defendant said he was seated in (markers designate blood spatter identified by the prosecution).

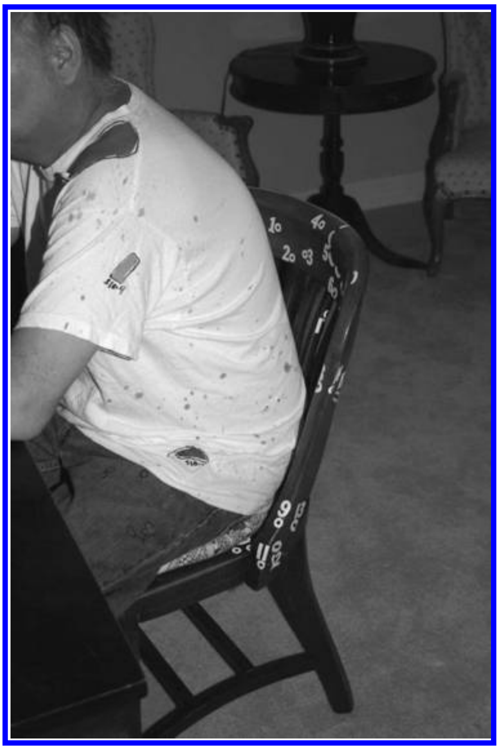


Figure 14.31 The defendant seated in the chair while wearing the clothing he had on at the time of the shooting (swatches removed for testing).

from the position the deceased brother was standing in according to bloodstains on the walls and ceiling). It should also be noted that there were two wingback chairs against the wall, one 9 feet and the other 11 feet from the decedent's probable standing position at the doorway (see Figure 14.31). Brain tissue from the decedent was distributed throughout the scene, some on the Venetian blinds behind the two wingback chairs.

Although apparently not examined by the prosecution, the defense examined the wingback chairs and found numerous tiny bloodstains distributed across both chairs (Figures 14.32 and 14.33).

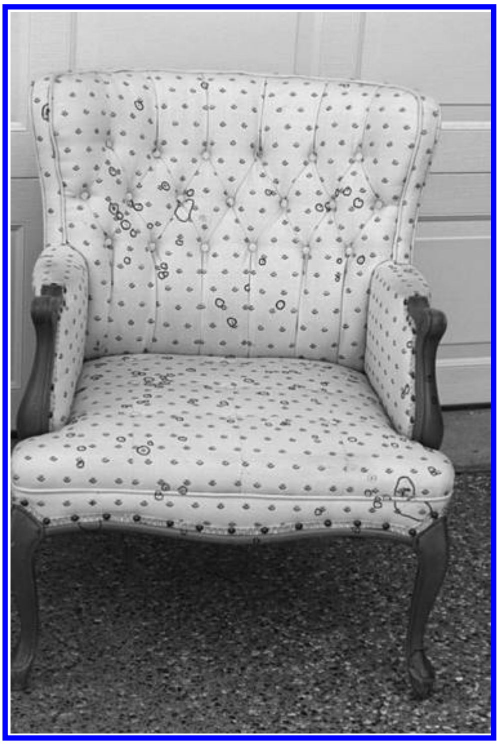


Figure 14.32 One of the two wingback chairs (bloodstains are circled in black).

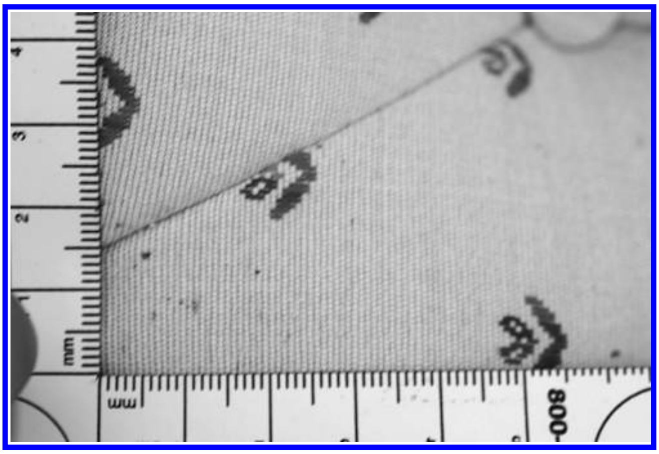


Figure 14.33 Close-up of chair blood (prior to marking).

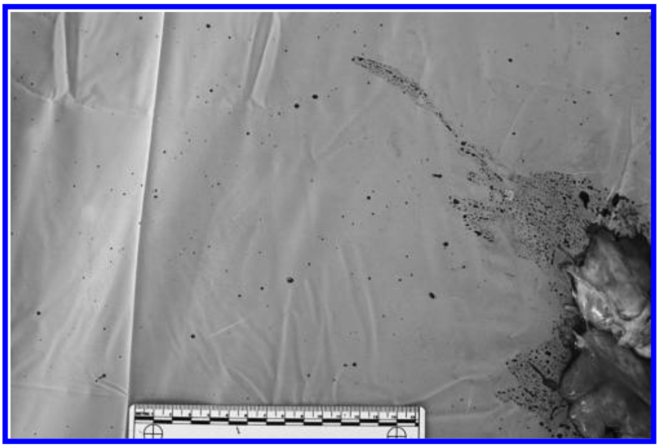


Figure 14.34 **(See color insert.)** Pseudo–back spatter produced at 14 feet.

But how could tiny drops of blood defy the laws of physics and travel across the room 11 feet or more? The answer, of course, is they cannot. Therefore, there has to be some other explanation. Because there was bloody brain tissue throughout the scene, could that have produced what could be termed pseudo-impact spatter? That could only be answered through testing. Obviously, any such testing could only be proposed as representing the maximum possible impact spatter obtainable under the test conditions. Those test conditions were as follows:

- Bovine thymus tissue impregnated with human blood was placed in a plastic bag suspended approximately 6 feet above the ground (the height of the entry wound).
- Plastic sheets were laid out on the ground below out to 15 feet (front and rear).
- A 12-gauge shotgun slug was fired at contact distance into the tissue/blood sample.
- Maximum distance for forward and back spatter was recorded.

As already stated, this setup can in no way be considered to be representative of the circumstances of the shooting. The goal was to determine whether airborne bloody tissue could slough off blood that would be consistent with impact spatter in size and appearance (i.e., the proposed hypothesis needed to be tested). The result is shown in Figure 14.34.

The sloughing off of blood by the bovine tissue confirmed the hypothesis. Clearly, if apparent impact spatter (albeit pseudo-spatter) was present on objects well beyond the defendant's position, it would be logical that his clothing would have it as well. After this and other exculpatory evidence was presented by the defense, the defendant was acquitted.

Locating Latent Bloodstains

The location of otherwise invisible bloodstains at shooting scenes is something a shooting scene reconstruction expert should be well versed in and put to use with regularity. The historically significant reagent that has been used for many years, luminol, has pretty much been transcended by a luminol variant marketed under the name Blue Star Magnum™. Blue Star has the advantage of being effective in moderate light, whereas luminol requires

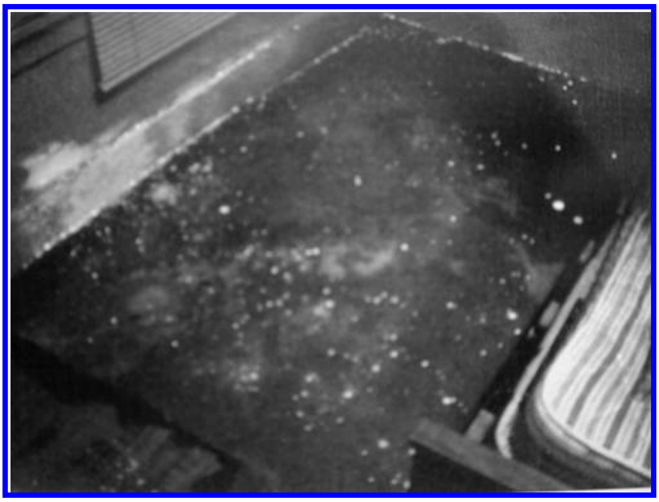


Figure 14.35 Latent bloodstains at a shooting scene revealed with Blue Star reagent.

total darkness. This translates to greater ease of documentation (i.e., photography). The reactivity of both is comparable, making Blue Star the go-to reagent for most investigators (Figure 14.35). Basically, the quest for otherwise latent bloodstains should be initiated at every scene where blood has been shed. To not do so is doing less than a thorough job and leaving one's flank exposed to attack from the opposing side at trial.

Exercises

1. Gunshots produce
   a. Forward and back spatter
   b. Only forward spatter
   c. Only back spatter
   d. It depends on a number of variables
2. Impact spatter on/in a weapon is characteristic of
   a. Contact shot
   b. Near contact shot
   c. Distance shot
   d. Both a and b are correct
3. Impact spatter on the hand of a shooter is indicative of
   a. Suicide
   b. Homicide
   c. A defensive posture
   d. It cannot be determined without additional information
4. When tiny blood spots are present with a "fisheye" appearance, it means
   a. Expirated blood is likely
   b. The blood was partially wiped up
   c. A gunshot was involved
   d. No saliva was present

5. When no impact spatter is found it means
    a. No gunshot was involved
    b. Expirated blood was the source
    c. Blunt force trauma was involved
    d. No determination can be made without more information
6. When there are both tiny bloodstains and larger bloodstains present in a pattern it means
    a. It could not be a gunshot
    b. A gunshot could be involved
    c. A head shot was involved
    d. A contact shot was involved
7. Which of the following is most likely to produce back spatter?
    a. Head shot at 2 inches
    b. Chest shot at 8 inches
    c. Foot shot from 12 inches
    d. Leg shot from 2 feet
8. Which one of the following is most likely to produce back spatter (all else being equal)?
    a. A 12-gauge shot gun
    b. A .22 revolver
    c. A .38 special revolver
    d. A 9-mm pistol
9. Which one of the following would be most likely to reduce back spatter totally or partially (all else being equal)?
    a. T-shirt
    b. Heavy coat
    c. Medium length hair
    d. Tight jeans
10. Blood spatter designated as high impact spatter would be produced by
    a. Blunt force
    b. Gravity (dripping)
    c. Cast off
    d. Gunshot
11. Blood spatter that would travel the greatest horizontal distance from its source would probably (all else equal) be produced by
    a. Gunshot entry wound
    b. Blunt force trauma
    c. Expiration of blood
    d. Gunshot exit wound
12. With gunshots, more blood spatter is produced
    a. In the forward direction
    b. In the rearward direction
    c. Inside the wound
    d. At impact

13. High impact blood spatter has a diameter of
    a. 1 mm or less
    b. 1–3 mm
    c. 3–5 mm
    d. Greater than 3 mm
14. Blood spatter from a gunshot can travel horizontally about
    a. 2 feet
    b. 4 feet
    c. 6 feet
    d. 10 feet
15. Other types of bloodstains that may be present at shooting scenes in addition to impact are
    a. Passive blood flow
    b. Satellites from blood dripping into blood
    c. Transfers
    d. All of the above

    Answers: (1) d, (2) d, (3) d, (4) a, (5) d, (6) b, (7) a, (8) a, (9) b, (10) d, (11) d, (12) a, (13) a, (14) c, (15) d

Suggested Readings

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Officer-Involved Shootings

15

General Considerations

When a police officer is involved in a shooting incident in the line of duty, it is critical that each aspect of the necessary scene documentation be done with the utmost care and thoroughness. This is not because an officer-involved shooting carries any more significance than any other type of shooting, but because this type of shooting is sure to attract maximum scrutiny at both the criminal and civil levels. Ever since the Rodney King police beating incident in Los Angeles in 1991, police officer use of force at all levels has remained the subject of intense review and discussion, reaching an extreme point with the Michael Brown shooting in Ferguson, Missouri, in 2014 by a Ferguson police officer.

The standard operating procedure for most police agencies is to launch simultaneous administrative and criminal investigations when an officer has been involved in a shooting incident. Many police agencies have shooting review teams or boards that, in effect, reconstruct officer-involved shootings. As with any shooting reconstruction, the success or failure rests with the quality of the scene documentation.

Although the general approach to the reconstruction of an officer-involved shooting should be no different than that of any other shooting, there are a number of special considerations that must be addressed in officer-involved shooting reconstructions. A suggested protocol for the documentation of the physical evidence in an officer-involved shooting is as follows.

Protocol for Officer-Involved Shootings

1. Gunshot residue (GSR) tests should be conducted on all persons (including officers) at the scene who could have possibly been involved in the shooting incident.
2. All weapons (including officers' weapons) should be taken into evidence at the scene for function testing and firearms identification (bullet/cartridge case comparison, distance determination testing, and ejection pattern testing as appropriate), making sure to note position of safeties, presence of trace evidence, and loading status (Figure 15.1).
3. Cartridge case/shot shell locations in the scene need to be properly documented and appropriate measurements recorded.
4. All bullet/pellet holes/impacts need to be measured for diameter and, if GSR is a consideration, GSR lifts taken from the surface of all bullet/pellet holes/impacts and the surrounding material.
5. Measurements of all bullet/pellet holes/impacts that fix their locations (i.e., *x*, *y* coordinates) need to be taken.
6. All bullet/pellet holes/impacts need to have their *x*, *y* angular coordinates determined for trajectory determination (Figure 15.2).

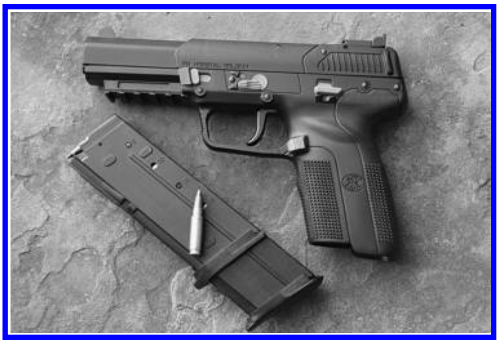

Figure 15.1 Weapon collection and loading status check must be completed.

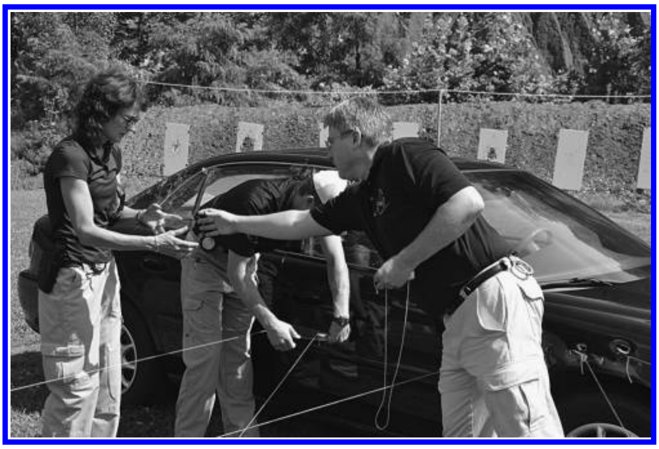

Figure 15.2 Bullet trajectory determination.

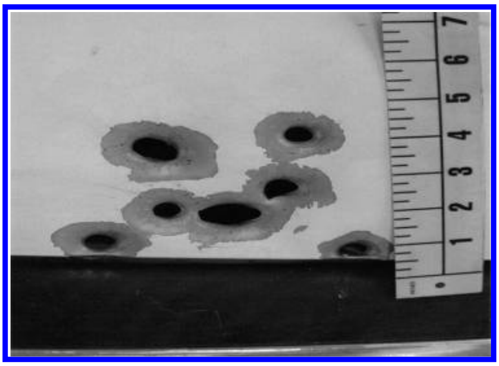

Figure 15.3 Shotgun pellet pattern.

7. Shot shell pellet patterns need to be measured as to length and width (or diameter if circular) when appropriate (i.e., a complete, recognizable pattern is present) (Figure 15.3).
8. If footwear impressions are a possible consideration at the scene, officers' shoe impressions need to be taken or the shoes/boots themselves taken into evidence along with those of the suspect(s) and witnesses.
9. Clothing worn by anyone at the scene having bullet/pellet holes needs to be taken into evidence for GSR/distance determination testing.
10. Any clothing bearing possible blood stains, tears, soiling, etc., needs to be taken into evidence for further examination/testing.
11. All blood spatter patterns need to be appropriately documented and representative samples taken.
12. If trace evidence is a potential factor, appropriate control samples (i.e., hairs, fibers) need to be collected from all individuals present including officers and all clothing taken and packaged separately to prevent cross-contamination.
13. All minor wounds, scratches, abrasions, etc., that are potentially related to the incident need to be documented photographically.
14. Any bullet ricochets need to be photographed and impression casts prepared of ricochet creases.
15. If tire impressions are a potential consideration, test impressions of all vehicles need to be prepared.
16. Shot accounting should be done before releasing the scene to minimize the chances of leaving fired bullets/cartridge cases behind.
17. Proper documentation needs to be completed while on-scene (i.e., sketches and photographs taken) and appropriate logs completed (i.e., Scene Entry log, Photo log, Evidence Collection log).
18. A final review of all documentation and evidence should be undertaken before releasing the scene.

In officer-involved shootings where more than one officer is present, there is often no apparent question as to which officer did the shooting. All officers at the scene typically agree as to who fired and who did not. As a general rule, however, it is important to follow the same protocol for every officer at the scene. With regard to GSR testing, it is both appropriate and recommended that GSR sampling be done on the hands of all officers involved. Appropriate sampling involves the use of adhesive-backed aluminum disks that are designed for scanning electron microscopy x-ray fluorescence (SEM-XRF) analysis. The collection of these samples does not necessarily dictate that the SEM-XRF analysis be done. The samples, once collected, can be maintained and available should a question ever arise as to other officers having possibly fired shots. Not collecting these samples at the scene could subject the department to needless criticism and possibly set the stage for allegations of cover-up.

The same reasoning applies to taking the weapons of all officers present into evidence for determination of loading status, trace evidence examination, and function testing. Officers should be instructed that this is a routine procedure that will be followed in all officer-involved shootings. So as to lessen the impact of having to give up their service weapons after a shooting incident, most departments issue officers involved in shootings substitute firearms until theirs can be returned. The recording of loading status needs to take place at the scene and officers need to be instructed not to reload before the arrival of investigators. The caveat for loading status determination is that the weapon did, in fact, have a round in the chamber and a full magazine before the shooting. Sometimes this is not the case, even though an officer may believe that it was. From time to time, officers fail to add an additional round to the magazine after loading the magazine and chambering a round at the start of their shift. Accordingly, when there is one unexplained missing round, consideration must be given to the possibility that the weapon did not have a full magazine to start with.

Most large departments have their own armorers who are responsible for the repair and maintenance of departmental weapons. These armorers can carry out function testing and examine officers' weapons to ensure that they meet departmental standards (i.e., have not been modified in any way). The downside to having a police armorer carry out examination/testing of officer's weapons is that they are typically not trained or qualified in the area of trace evidence analysis. The presence of hairs, fibers, blood, paint, glass, and other trace evidence on/in an officer's weapon can be important to the reconstruction of a shooting. Therefore, the best policy for a department to follow in the investigation of an officer-involved shooting is to have officers' weapons examined/tested by a firearm examiner in a forensic laboratory. This way, any trace evidence present can be turned over directly to a trace evidence analyst.

Advances in DNA technology allow the identification of DNA on weapons, ammunition, holsters, batons, and so forth. Whenever an officer-involved shooting involves a struggle over the officer's weapon/holster or other contact with the officer, consideration should be given to either swabbing the surface of the involved item or collecting it for DNA testing. This can be used to help confirm an officer's statement that an assailant tried to take away his weapon, for example.

In the author's experience in investigating officer-involved shootings, trace evidence examinations of officers' weapons are frequently overlooked, particularly when the weapons go to an armorer rather than to the crime laboratory. A forensic firearm examiner can carry out all the testing that an armorer would do in addition to the specialized forensic testing that they alone are responsible for (e.g., bullet/cartridge case comparisons).

Another standard test that should be conducted on officers' weapons is trigger pull determination. This will reveal the occasional instance where officers have modified their weapons by installing lighter trigger springs. This is usually out of departmental policy and can contribute to unintentional firing. This is the type of thing that a department facing a lawsuit needs to be aware of early on in the process, hence the importance of this testing.

It should be a matter of routine procedure that all ammunition components (i.e., bullets/fragments, cartridge cases, and shot shells) are documented as to their location in the scene. An equally routine procedure should be the forensic comparison of these ammunition components with the suspected weapons used. Once again, the fact that there is no apparent question as to which officer did the shooting does not preclude this aspect of the investigation. Figure 15.4 illustrates an officer-involved shooting scene.

When cartridge case/shot shell locations are properly documented and direction of firing is known, the position(s) of the shooter(s) may be established through ejection pattern testing. This testing has been described in a previous chapter in detail. The actual testing need only be carried out when deemed necessary and appropriate. It is not generally

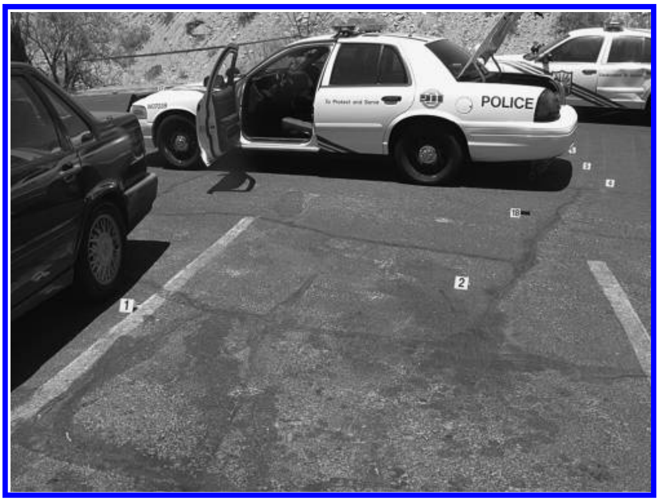

Figure 15.4 Fired cartridge case locations marked.

necessary to carry out ejection pattern testing in every shooting incident, officer-involved or not.

As in any shooting analysis/reconstruction, the *x*, *y* linear measurements and the *x*, *y* angular measurements need to be determined for each and every bullet/pellet hole. In addition to providing a means of documenting trajectories, this allows for the production of a scale diagram and/or computerized animation (Figures 15.5 through 15.7).

Many police departments issue Remington 870 12-gauge shotguns to their officers. The most frequently issued round is the Federal 00 buckshot buffered load. Accordingly, the pellet pattern produced by any shots to doors, walls, etc., should be measured for approximating the impact angle and muzzle-to-target distance. The general rule of thumb of an

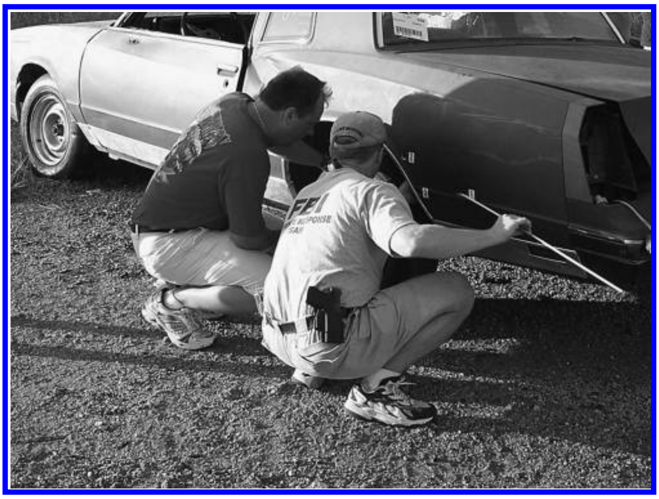

Figure 15.5 Establishing approximate pre-impact bullet trajectory.

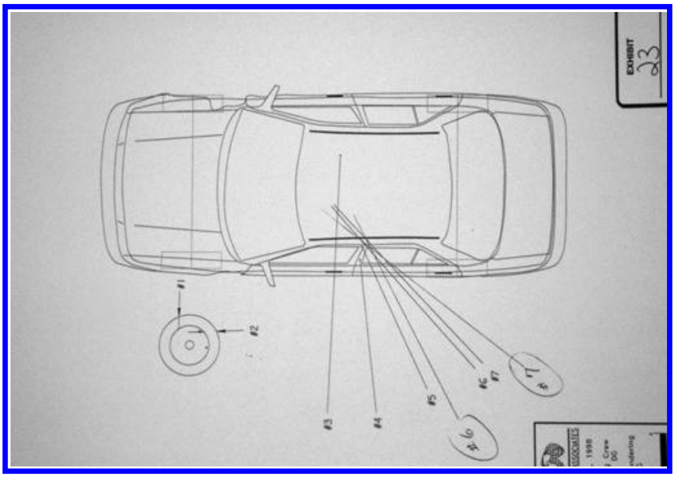

Figure 15.6 Scale drawing of approximate pre-impact bullet paths.

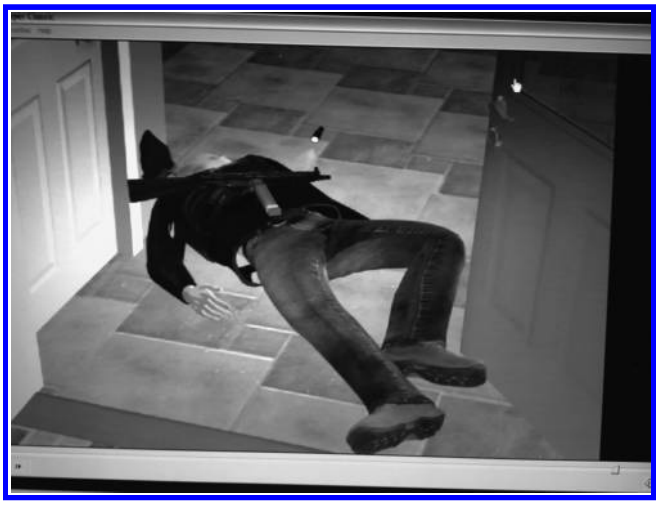

Figure 15.7 Computerized animation.

inch of pellet pattern diameter (width in the case of oblong patterns) to a yard of muzzle-to-target distance can be used for the purpose of beginning a search for evidence of shooter position. The calculation of approximate angle of impact based on the width and length of the overall pattern and/or several well-defined individual pellet holes further defines the area to be examined.

Footwear impression evidence is frequently an afterthought at crime scenes following what might be categorized as a parade of individuals through the crime scene. This means that there is the possibility, if not probability, of the obliteration of evidence footwear impressions by officers and other responders moving through the scene during the early stages of the investigation. To reduce or prevent this, the scene needs to be sealed off as soon as possible and entry controlled as strictly as possible and an entry log kept.

The presence of officers' footwear impressions can be used to establish involved officers' positions during shooting incidents as well as those of other involved individuals. When noninvolved individuals have moved through the scene, impressions of their footwear need to be obtained for elimination purposes. These known impressions may be taken at the scene. This approach minimizes wasted time spent with footwear impressions that do not belong to the participants in a shooting by allowing on-scene evaluations to be made. Otherwise, all visible footwear impressions must be considered in the reconstruction until appropriate eliminations can be made (Figures 15.17 through 15.24 show the sequence of events leading up to the fatal shot).

Clothing (uniforms and street clothing) of officers involved in shooting incidents should be taken into evidence and carefully examined for bullet/pellet holes, GSR, blood, rips/tears, and other possible trace evidence to assist in reconstructing the shooting. Simply taking photographs of the officer wearing the clothing is inadequate to properly document any related evidence.

The proper documentation of bloodstains at the scene includes taking overall photographs and close-up photographs being sure to include appropriate identifiers and scales. Dividing stained areas into zones and using both vertical and horizontal (x, y) scales simplifies documentation and subsequent interpretation. Additionally, representative samples need to be collected for analysis.

Tire tread impression evidence can also be a consideration in an officer-involved shooting reconstruction. As with footwear impression evidence, photographing with the camera at 90° to the impression and casting with dental stone provides appropriate documentation. Making elimination impressions of uninvolved tire treads requires taking all four tire impressions on paper. A technique developed by the author involves spraying a heavy coat of silicone release agent onto the tire tread surface and then driving along a piece of heavy paper taped to a piece of smooth plywood. The silicone spray provides an invisible image of even the finest detail on the tire tread that is developed by immediately brushing with a magnetic wand and magnetic fingerprint powder. A scene with tire tread evidence is illustrated in Figure 15.8.

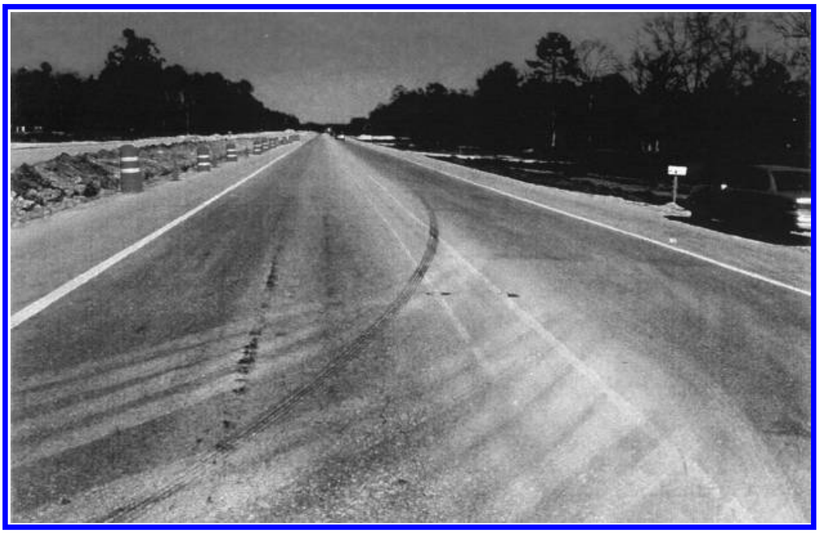

Figure 15.8 General overview of tire tracks (close-up photos taken directly overhead with scales in place are also required).

Unintentional Discharge of Weapons

There are a number of potential mechanisms by which unintentional discharge of a weapon can occur. These include the following:

- Poor weapon design
- Carelessness
- Inadequate training and/or ongoing weapon familiarity
- Sympathetic firing (involuntary muscle response)
- Loss of balance
- Being startled

Poor weapon design for police use can cause or contribute to unintentional firing. When police departments went from revolvers to semiautomatics years ago, the incidences of unintentional firing increased as a result of the ease of firing a semiautomatic pistol as compared to a revolver (when fired double action). Given the fact that most police shootings involve less than six shots fired by an officer, modern high capacity magazines are usually adequate. A typical police-issue Glock pistol is illustrated in Figures 15.9 and 15.10.

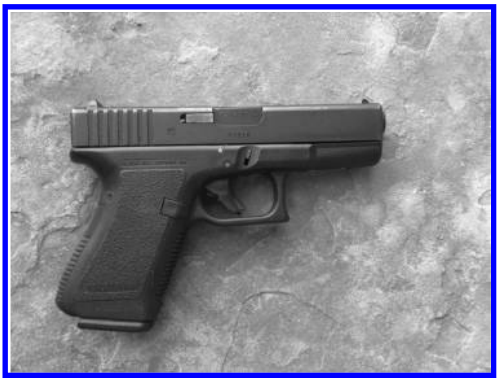

Figure 15.9 Typical police-issue .40 caliber Glock semiautomatic pistol.

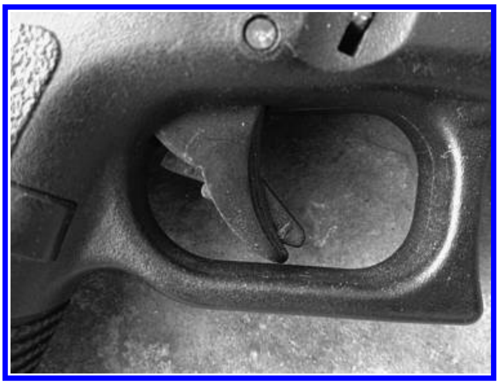

Figure 15.10 Glock trigger safety eliminates firing unless trigger is pressed.

There are two considerations regarding semiautomatic weapon design for police use. The first consideration is trigger pull. Trigger pull for a police-issue semiautomatic pistol should be in the 8–12-pound range for maximum safety. Trigger pulls at or below 6 pounds are used by some departments, but heavier trigger pulls are recommended. As stated in an earlier chapter, New York City Police special order 12-pound trigger pulls in all their Glock semiautomatic pistols in an effort to minimize the potential for unintentional firing by officers. Any discharge of an officer's weapon at the New York Police Department initiates a firearms discharge review panel inquiry.

The second consideration with regard to semiautomatic pistols is the length of travel of the trigger while under resistance before the weapon fires. The length of trigger travel under resistance can be just as important a consideration in unintentional firing as the trigger pull. Weapons with very short trigger travels under resistance, say 1/10th of an inch or less, before firing occurs are very unforgiving. Having a longer trigger travel under resistance before firing of 3/8 to 3/4 inch does not appear to present any tactical disadvantage and offers added assurance against unintentional discharge. In comparing trigger pull to trigger travel, a higher trigger pull does not compensate for a very short trigger travel. Thus, the combination of higher trigger pull and longer trigger travel is probably the best bet for law enforcement use.

Carelessness and human error are probably responsible for more unintentional shootings than any other cause. As the old saying goes "An awful lot of people have been shot with 'unloaded' guns." Police officers can be careless just like any other person. Failure to follow basic firearm safety rules happens from time to time. In a very tragic case the author reviewed, a police officer shot and killed a fellow officer during a training exercise in which no live ammunition was supposed to be present. This was done in the presence of a class of police cadets who were there to observe how to disarm a suspect. In spite of well-known and well-established safety rules to the contrary, the officer who fired the fatal shot had not had his weapon inspected to ensure that no live ammunition was present before the start of the exercise.

Other than during their police academy firearms training session, many police officers get little in the way of ongoing, extensive firearms training. Regular and frequent training with a weapon makes the user familiar with its inherent characteristics to the point that, during a critical incident, the operation of the weapon becomes second nature.

Sympathetic or involuntary firing is the pulling of the trigger and firing of a gun as a result of an intense contraction of the non-gun hand. This most often occurs when an officer has a gun in one hand while trying to handle a suspect with the other hand. According to studies conducted by Dr. Roger M. Enoka at the Cleveland Clinic, an average force of 100 pounds can be applied by the grip of a 20- to 30-year-old male.

A sympathetic nervous response when one hand is tightly contracted results in up to 20% of the force being imparted to the other hand. Further research has shown that approximately 30% of the force is exerted by the index (trigger) finger. Thus, 6 pounds of force can be applied to the trigger finger when the opposite hand is used to tightly grip someone or something. This is why officers are trained not to hold a weapon and have their finger on the trigger when handling someone. Of course, things do not always go according to the book during an altercation with a suspect. In any officer-involved shooting where a struggle occurred during which an officer fired shots, consideration of unintentional firing must be given.

Similarly, if an officer is moving toward a suspect with gun drawn and stumbles or trips, an involuntary pulling of the trigger can result. This, of course, is another reason why officers are trained not to keep a finger on the trigger until it is appropriate to do so. This is often an uncertain issue, however, and a decision that an officer must make on the basis of perceived danger at a given moment. When a suspect is unintentionally shot by an officer, the second guessing and armchair quarterbacking inevitably run rampant.

Another common reason for the unintentional discharge of a weapon by an officer results from being startled while having a finger on the trigger. This can result from a variety of events, but a common one is in response to the discharge of a weapon by a fellow officer who is close-by. For example, when several officers have a suspect at bay and all the officers have their weapons drawn and at the ready, an inadvertent discharge by one of the officers often sets off firing by everyone. The author has observed this in a number of police-involved shootings that he has reviewed.

A tragic example of an unintentional shooting by an officer resulted in the death of a criminal justice instructor in her own home. The instructor had been left a message at her school by an alarm company around noon advising her that her home intrusion alarm was going off at the back door. After receiving the message, the woman left school and headed home to check on things. Thinking an actual burglary was unlikely, given the neighborhood and the time of day, she pulled her vehicle into her garage, leaving the engine running, while she walked into the house through a side entrance and went to check the back door. Unbeknownst to the homeowner, the alarm company had contacted local police when they could not reach her. An officer pulled up in front of the house just after the homeowner arrived (Figure 15.11).

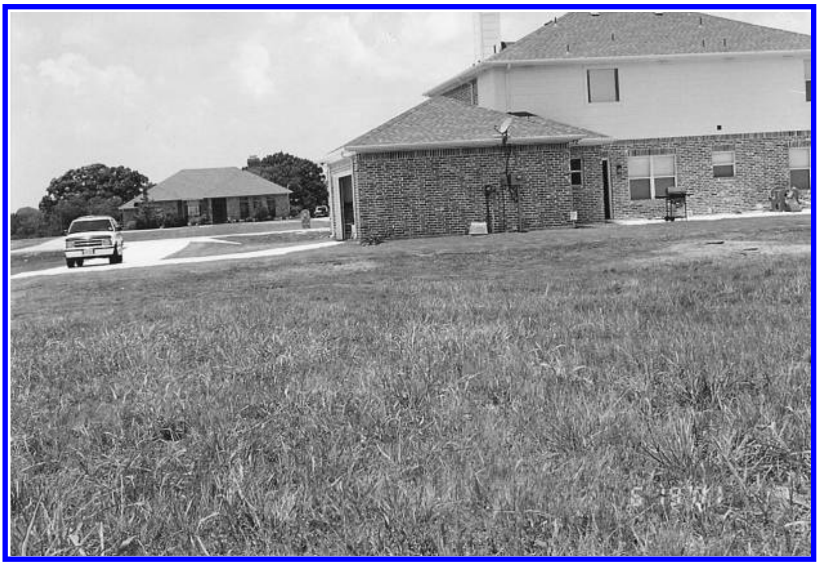

Figure 15.11 Police vehicle at residence (victim's vehicle is in the garage with engine running).

Rather than running the license plates of the homeowner's car or wait for backup to arrive, the officer exited her vehicle, drew her Glock 9-mm service pistol and started walking around the house to the back door (several neighbors watched from their homes as this all unfolded) (Figure 15.12).

The officer stated that when she arrived at the back door it was ajar. She said that she had her pistol pointed toward the opening in the doorway as she grabbed the doorknob with her left hand. According to the officer, the door suddenly was pushed toward her, striking the muzzle of her pistol causing it to discharge. She said when she pushed the door open and looked inside she saw the homeowner down on the floor in a pool of blood (the homeowner was later pronounced dead at the scene). Figures 15.13 and 15.14 show the bullet perforation to the back door and the entry wound to the victim.

The bullet had passed through the door, entered the homeowner's left shoulder, exited her right shoulder, and struck the wall behind her. The bullet fell to the floor, where it was ultimately recovered. The bullet trajectory through the homeowner's body was consistent with her having been standing sideways at the back door with her left hand on the inside doorknob. This all seemed to fit the officer's version of unintentional discharge—or did it?

The officer's Glock pistol was examined by a crime laboratory firearm examiner and determined to be fully functional as designed (i.e., no malfunctions, correct trigger pull). But was the explanation that the discharge was the result of the door striking the muzzle

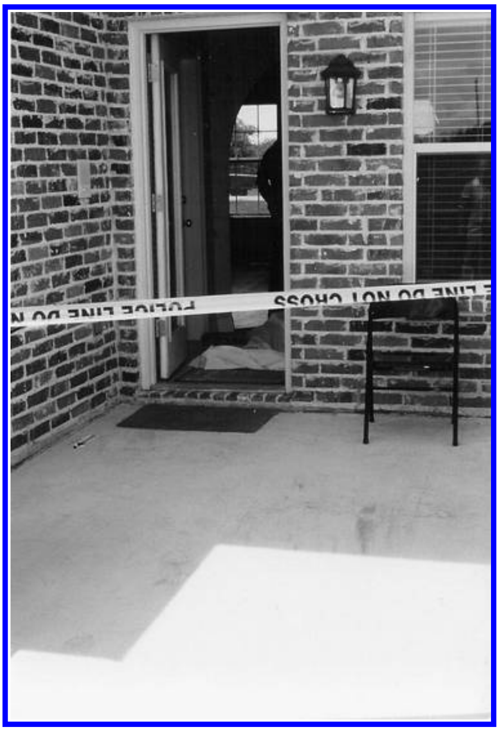

Figure 15.12 Back door to residence.

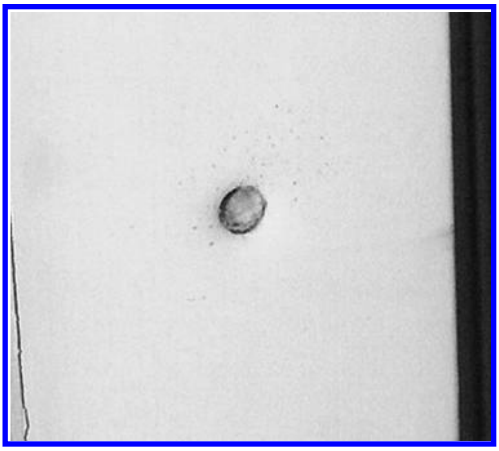

Figure 15.13 Bullet entry to back door.

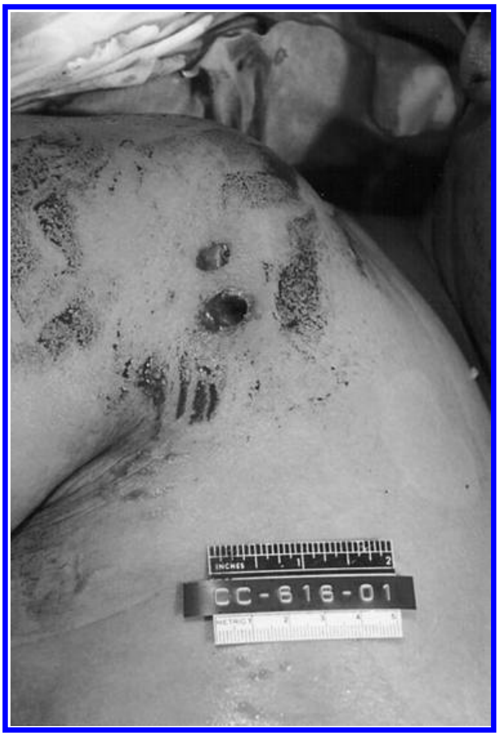

Figure 15.14 Bullet entry wound to left shoulder.

of the pistol acceptable? The short answer is NO! Contact with the muzzle of a Glock pistol like that the officer was carrying causes the barrel and slide to move rearward. The effect of that movement is to take the pistol “out of battery” rendering it unfireable.

Furthermore, if one considers the physics involved, even with the finger on the trigger (which had to have been the case here), a blow to the muzzle area of the pistol

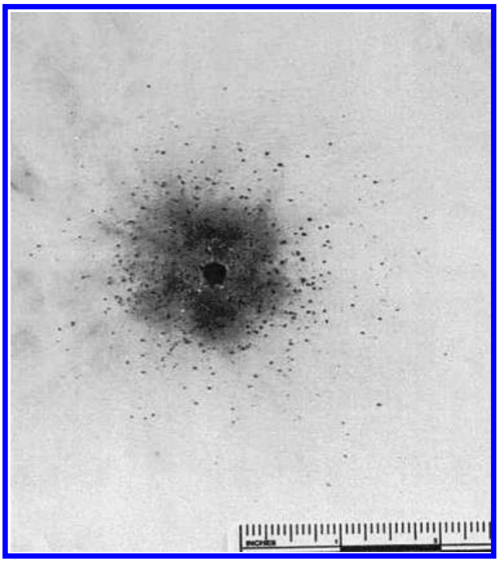

Figure 15.15 Test shot at contact distance.

would have caused the finger to move forward not rearward (sort of like having a bag of groceries on the backseat of a car and hitting the brakes—the groceries go forward).

The reader is asked to take another look at the bullet entry hole in the door (Figure 15.13)—note that there is no soot residue and there are apparent gunpowder particles visible around the entry hole. This is consistent with an intermediate-range shot, not a contact shot as the officer claimed! Now look at Figure 15.15, which shows a contact shot using the same type of ammunition as that of the officer.

This information was presented to the officer at an administrative hearing, upon which the officer admitted that what had really happened is she had been startled when the door moved and inadvertently pulled the trigger as a result. Unfortunately, her previous false testimony left the department with no other alternative but to dismiss her.

Accidental Discharge of Weapons

Accidental discharge of a weapon is distinguished from unintentional discharge in that accidental discharge is indicative of a weapon malfunction. Thus, accidental discharge is a mechanical malfunction whereas unintentional discharge has no mechanical aspect (save for the possible exception of the weapon having a much lighter trigger pull than department standard).

Mechanical malfunctions that result in accidental discharge of officers' weapons are rare. This is because modern police-issued weapons, such as Glocks, Sig Sauers, Berettas, and Smith & Wessons, have sophisticated, reliable safety mechanisms and are not prone to malfunction.

Any questions as to the possible malfunction of an officer's weapon that resulted in accidental discharge can be answered by the department's armorer. The armorer will be skilled in the maintenance and repair of the department's issue weapons. The armorer will probably be the "go to" individual for this kind of situation. In the absence of an armorer, a firearm examiner with a crime laboratory will often have comparable expertise in this particular area.

Suicide by Cop

The phenomenon known as suicide by cop occurs when individuals wish to die but are unwilling or unable to carry out the act by themselves. Synonymous terms include police-assisted suicide and self-precipitated suicide. There are a number of possible motivators for this act. These include the following:

- Avoidance of consequences (i.e., incarceration)
- Proving some emotional point
- Venting rage
- Suicide
- Homicide–suicide
- "Cry for help"
- Hoping to avoid insurance exclusion
- Avoiding the spiritual problem of suicide
- Seeking an effective method
- Need to save face

Officers are often given a number of possible indicators during the initial stages of confrontation with suspects bent on forcing the police to shoot them. Among these indicators are the following:

- Asks to be shot
- Indicates "won't be taken alive"
- Expresses desire to die
- States "Jail is not an option"
- Cites biblical references to Book of Revelations and resurrection
- Expresses hopelessness

In addition to verbal indicators, the following actions can be indicative of intent to force officers to shoot:

- Demonstrative with weapon
- Points weapon at police
- Shooting at police
- Countdown to kill hostages
- Forces confrontation
- Self-mutilation in front of police

- No escape demands
- Refuses to negotiate
- Continues aggression after wounding

There are a number of aspects in the backgrounds of individuals who become involved in confrontations with police that may indicate the intention to commit suicide by cop. These include the following:

- Has killed a significant person in their life (parent, spouse, child, etc.)
- Has killed a prized pet or destroyed valued possessions
- Has recently disposed of money or property
- Faces shame
- Faces certain imprisonment
- Has left a suicide note
- History of clinical depression
- Has been given a terminal diagnosis
- Has suffered two or more traumatic losses (loss of job, divorce, loss of a loved one)
- Has had previous police contact over suicide issues

There are a number of circumstances that officers are called upon to deal with that present extra potential for suicide by cop. These include:

- Domestic violence calls
- Armed robbery calls
- Person with gun calls
- Mentally disturbed individuals
- Known suicidal individuals
- Barricaded individuals
- “Three strikes” criminals

When reconstructing a shooting involving a police officer, some consideration as to the possibility that suicide by cop is involved should be given. Although the presence of the indicators presented here does not guarantee that suicide by cop was involved, further investigation as to that possibility is certainly warranted. The “why” aspect of a shooting reconstruction is not always an answerable question, but it is a relevant aspect of shooting reconstruction that should be explored, particularly in officer-involved shootings.

Case Studies

A Probable Case of Suicide by Cop

An officer on a routine patrol through a motel parking lot known for drug dealing and prostitution encountered a suspect that he recognized. Upon making eye contact with the officer, the suspect made an about-face and ran back down the stairs to the lower level. The officer exited his patrol unit and ran after the suspect, ultimately catching him and escorting him back to the front of his patrol unit. The officer had the man stand in front of the patrol unit while he ran a check on the man from his onboard computer, activating the dash camera in the process (Figures 15.16 through 15.21).

After determining that the man had outstanding warrants, the officer exited his patrol unit and came around to the front and advised the man that he was under arrest. As can

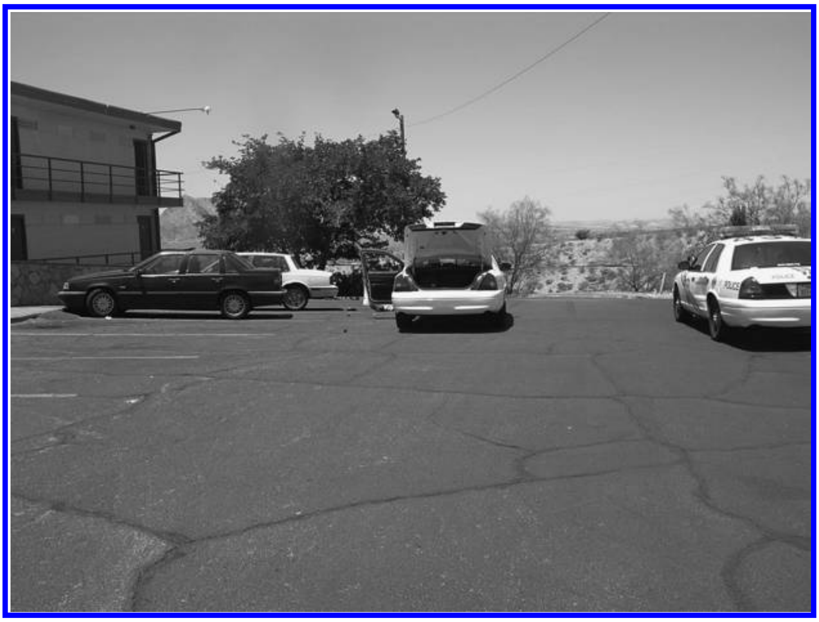

Figure 15.16 The scene (unit to right was backup unit that arrived later).

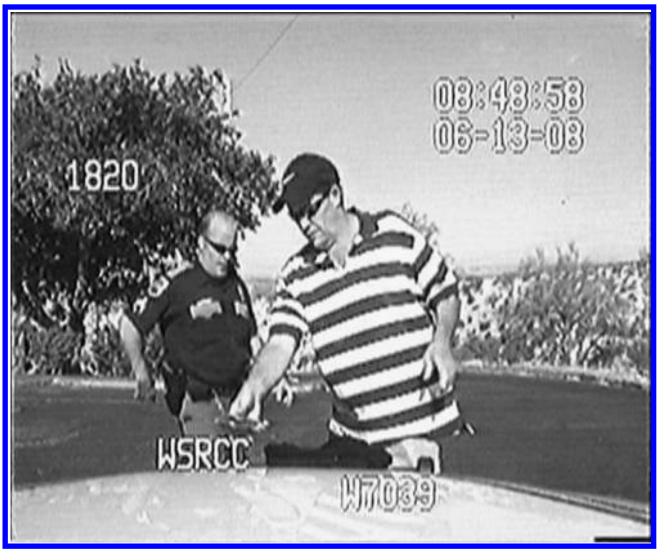

Figure 15.17 Officer with suspect.

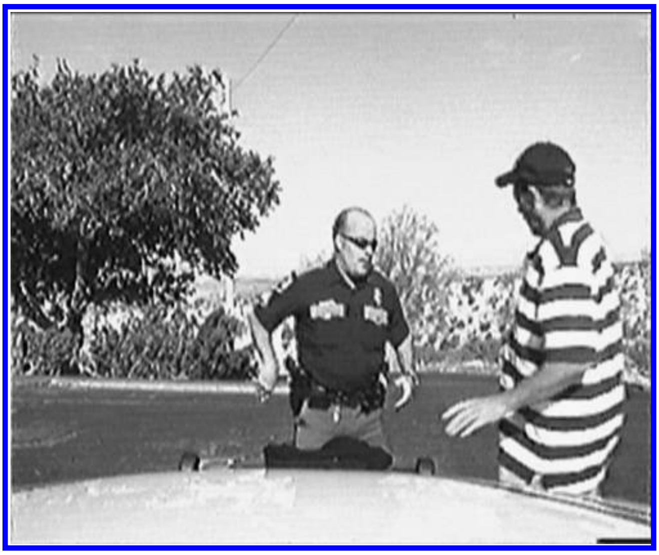

Figure 15.18 The suspect becomes uncooperative.

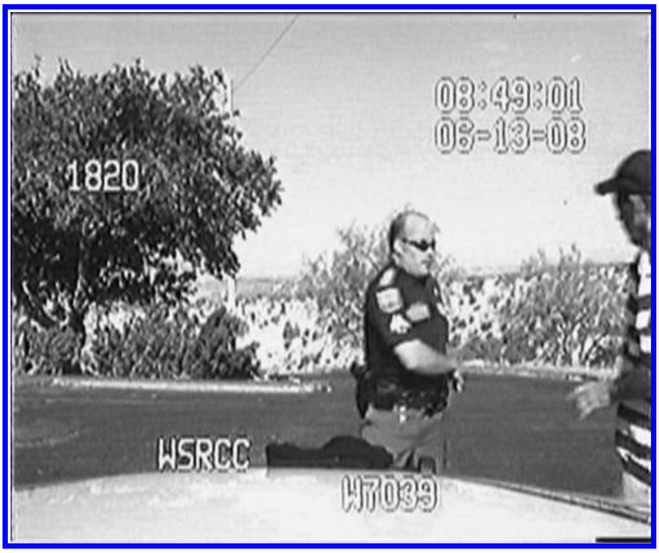

Figure 15.19 The suspect moves toward the passenger's side.

be seen in the images from the dash camera, the man became uncooperative and ran to the passenger's side of the patrol unit, pulled out what looked like a gun and yelled "I have a gun," whereupon the officer turned and ran back around the front of the patrol car drawing his gun as he ran. Once on the driver's side of his patrol car, the officer opened fire on the man (Figure 15.22).

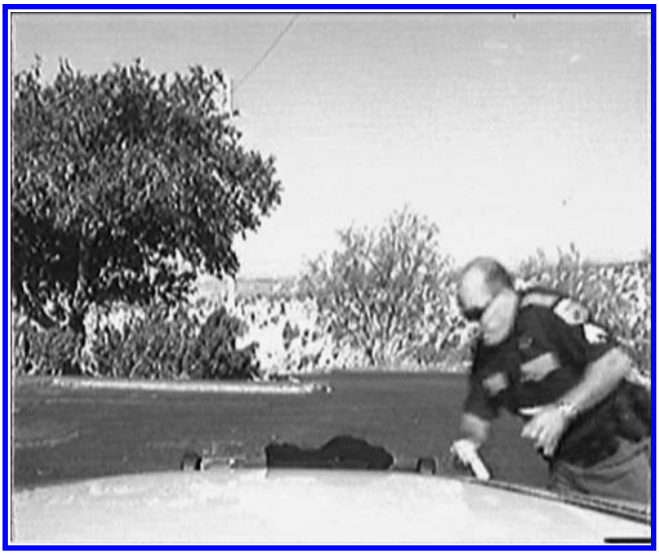

Figure 15.20 The suspect produces an apparent gun causing the officer to retreat.

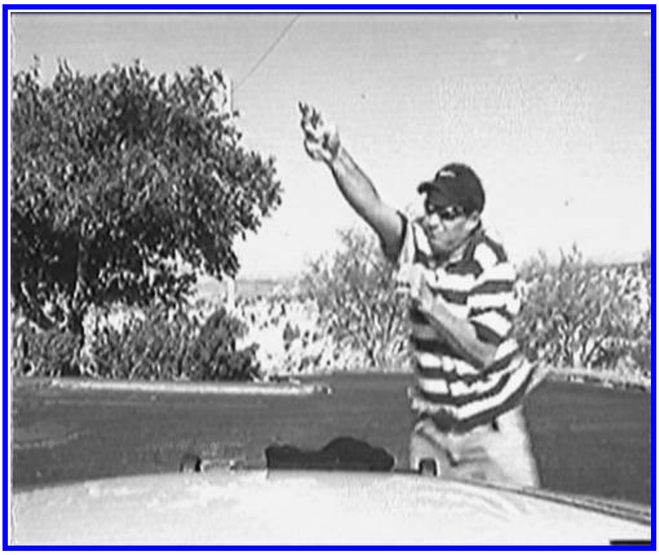

Figure 15.21 The suspect with what appears to be a gun.

No criminal charges result but a civil suit against the department is filed. Part of the basis for the civil suit comes from the medical examiner's (ME) report in which he opines that the fatal shot to the neck was the result of a ricochet. The ricochet theory being based on the punctate injuries to the chest (the ME stating they were produced by "bits of gravel knocked up by the ricochet") and what the ME described as an "atypical entry wound" (Figure 15.25).

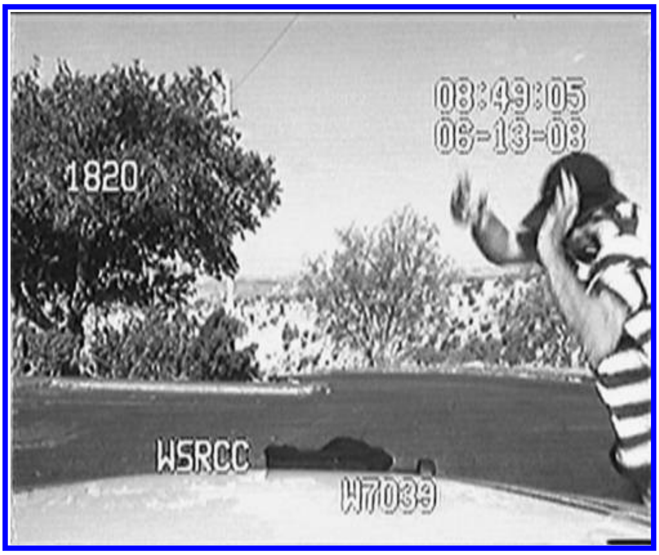

Figure 15.22 The officer opens fire and the suspect appears to be hit.

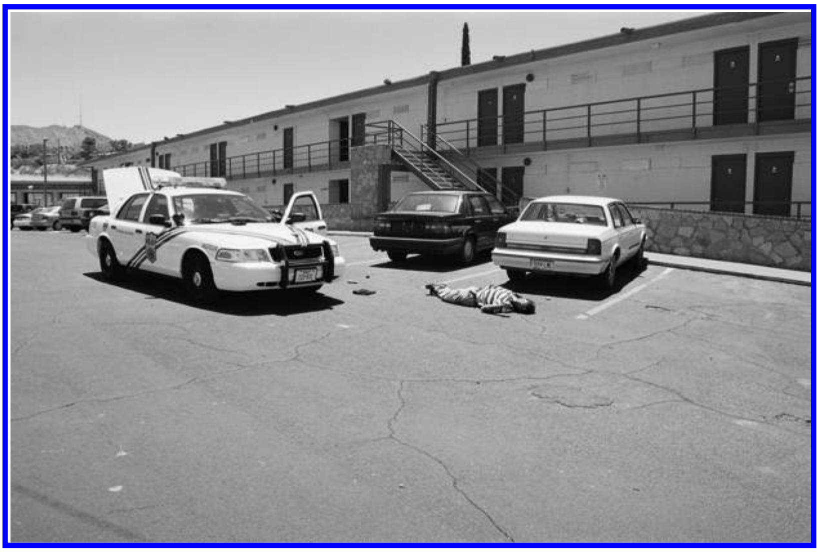

Figure 15.23 The suspect goes down.

To counter the opinions stated by the ME, the following observations were made:

- There was no sign of a bullet ricochet crease in the asphalt at the scene.
- There were no bits of gravel recovered at autopsy and none were found in the decedent's shirt (nor were there any holes in the chest area of the shirt).
- The bullet entry hole in the shirt collar was more or less circular.

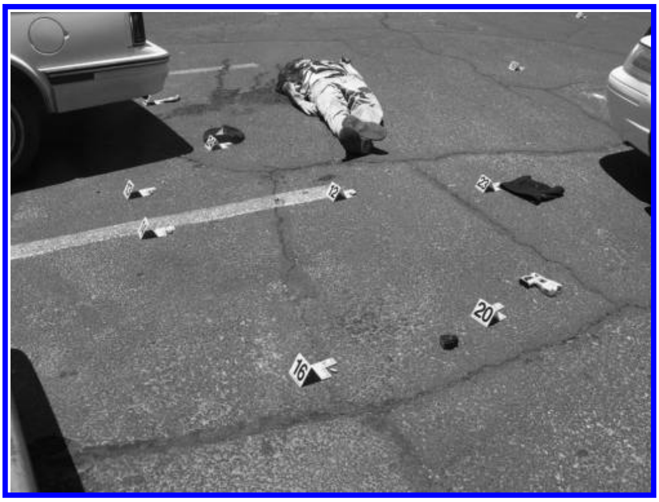

Figure 15.24 The location of fired cartridge cases and other evidence is marked.

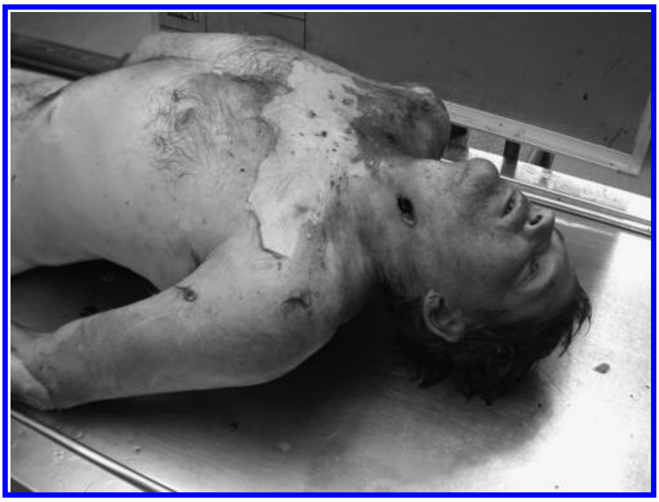

Figure 15.25 Autopsy photo showing skin burned away by hot asphalt, punctate injuries to chest, and entry wound to neck.

- The bullet recovered from the neck at autopsy was uniformly expanded.
- Dash camera images appear to show the suspect taking the shot to the neck (Figure 15.22), and an enhanced image shows a dark spot where the entry wound was (indicative of the neck shot having occurred before the suspect went down) (Figures 15.26 through 15.29).

The civil suit was effectively countered by the physical evidence that clearly was inconsistent with a ricochet having taken place after the man was already down and "lying

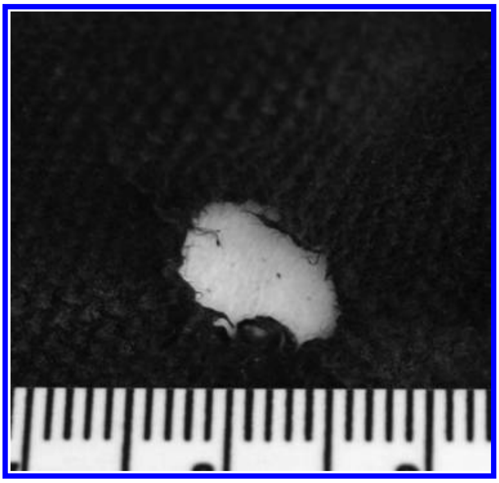

Figure 15.26 Bullet hole in shirt collar.

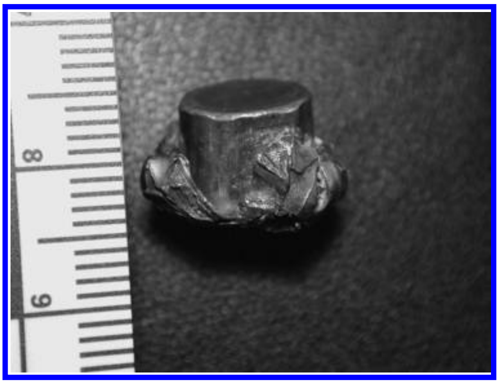

Figure 15.27 Uniformly expanded bullet from neck.

helplessly on the pavement" as alleged by the plaintiffs. The punctate injuries to the decedent's chest were likely from contact with surface gravel on the asphalt. This incident took place in the summer in an area where the air temperature was more than 100°F and the asphalt temperature considerably higher. Not having a board certified forensic pathologist involved was clearly not helpful!

Charles Whitman and the University of Texas Tower Incident

The author was attending classes at the University of Texas during the summer of 1966 when Charles Whitman barricaded himself at the top of the University of Texas tower with a large cache of guns and ammunition (Figure 15.30). As the author left his dormitory and headed for class, he was met by the sounds of gunfire coming from the mall area of the University of Texas tower. Rounding a building and coming into view of the mall, bodies were visible lying about in pools of blood.

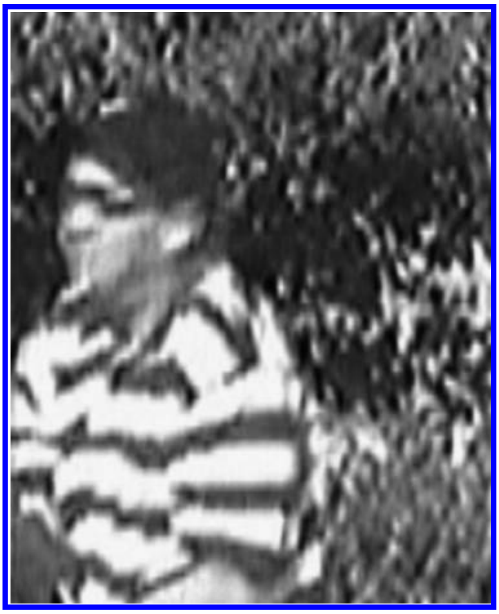

Figure 15.28 Enhanced image showing apparent entry wound to neck (dark spot).

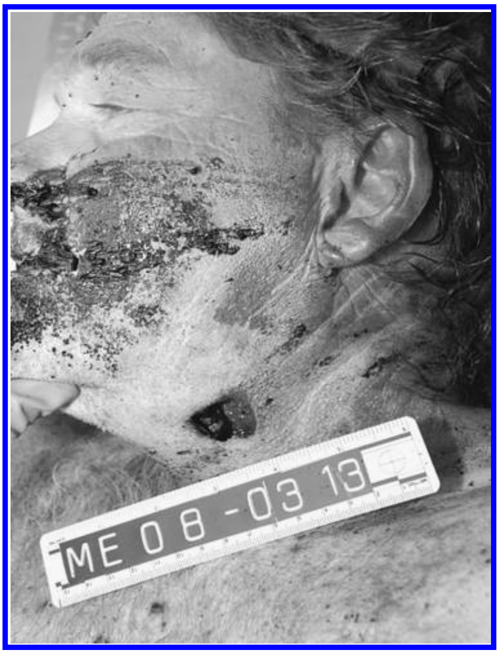

Figure 15.29 Entry wound to neck.

The author moved back around the corner of the building for cover just as a Texas Ranger took up a position directly at the corner with a 30-06 rifle with a scope. The author positioned himself behind the Ranger and about 10 feet away. As incoming shots from the tower continued, the Ranger took aim and fired several rounds before two Austin police officers, Houston McCoy and Ramiro Martinez, made their way up the tower elevator and shot and killed Whitman (Figures 15.31 through 15.37).

Figure 15.30 The University of Texas at Austin tower.

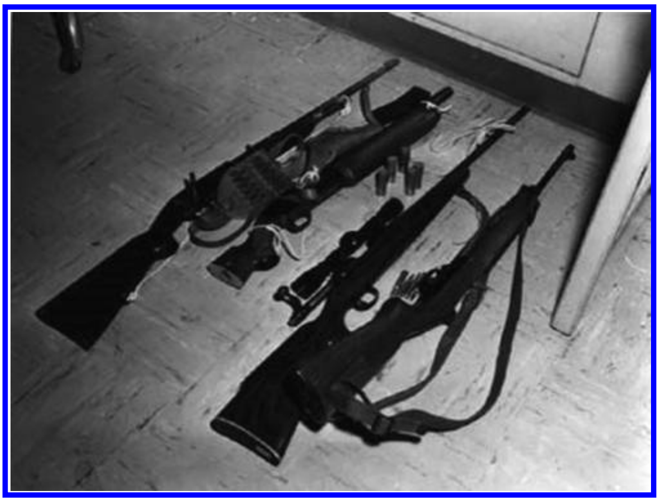

Figure 15.31 Long guns Whitman took up into the tower.

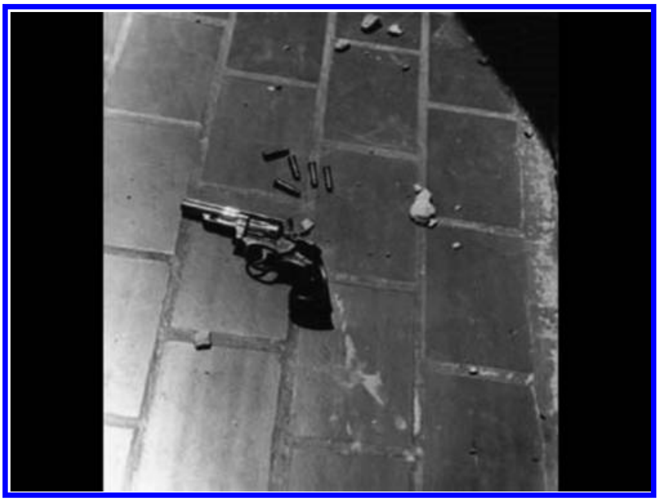

Figure 15.32 Smith & Wesson revolver Whitman had.

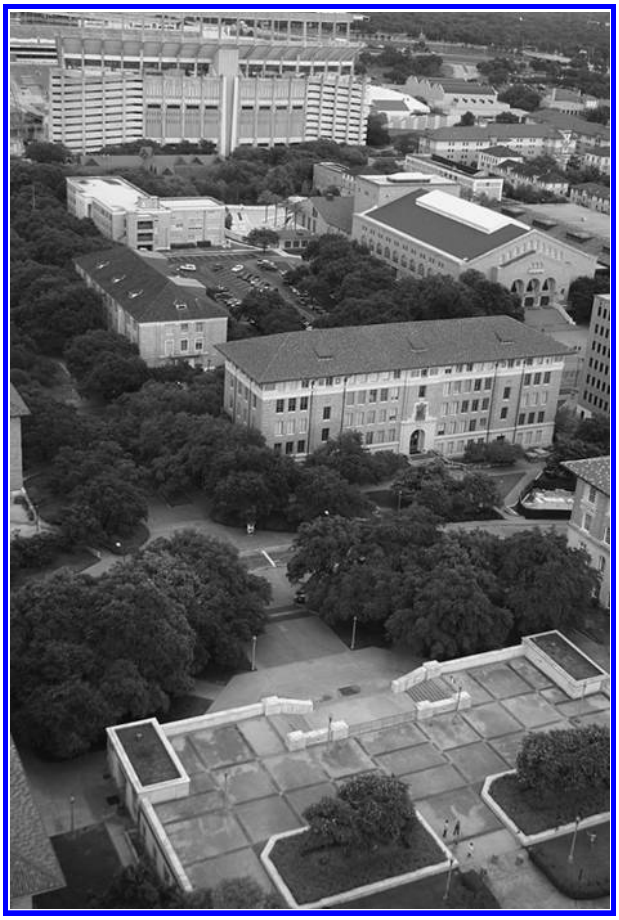

Figure 15.33 View of the quadrangle below the tower.

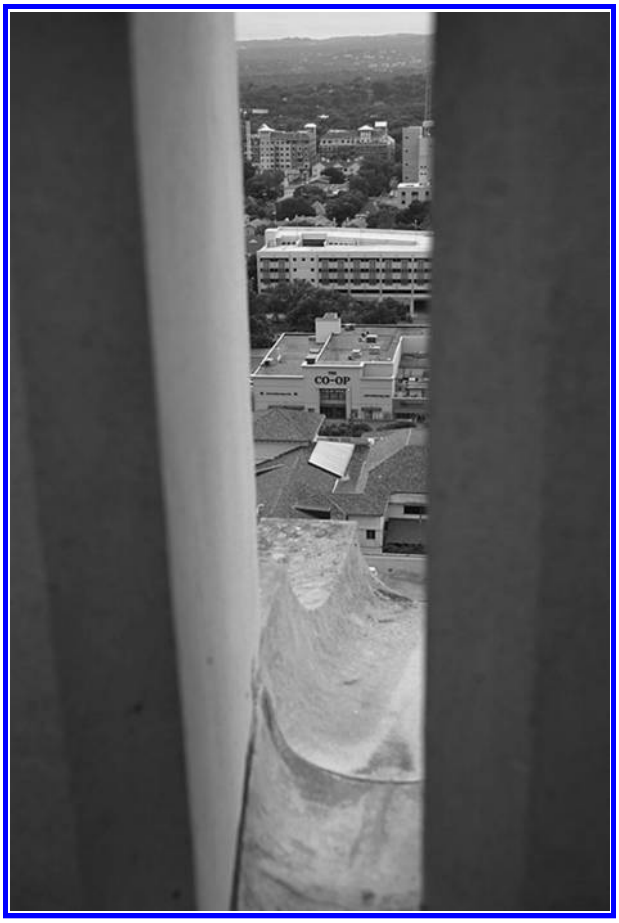

Figure 15.34 View Whitman had from the drain spouts around the top of the tower.

Whitman managed to kill 14 people and wound 31 before he was killed by McCoy and Martinez in what was an incredible act of bravery on their part. Most of the victims were shot with a Remington model 700 bolt action rifle in 6-mm caliber with a telescopic sight. Whitman also fired a .30 caliber semiautomatic carbine without a scope.

After Whitman's body was removed from the tower, it was learned that he had killed his mother and wife the day before. Whitman made no demands and had no contingency plan for escape. He clearly wanted to die, and he wanted to die in a big way. In this case, his wish was granted.

At autopsy, it was learned that Whitman had a walnut-size tumor in his brain. This caused some to speculate that he must have "snapped" as a result of the tumor and pressures from school (he was a graduate student in the school of architecture). This does not appear to have been the case, based on the meticulous plan he contrived and carried out. Rather, it was a clear case of suicide by cop.

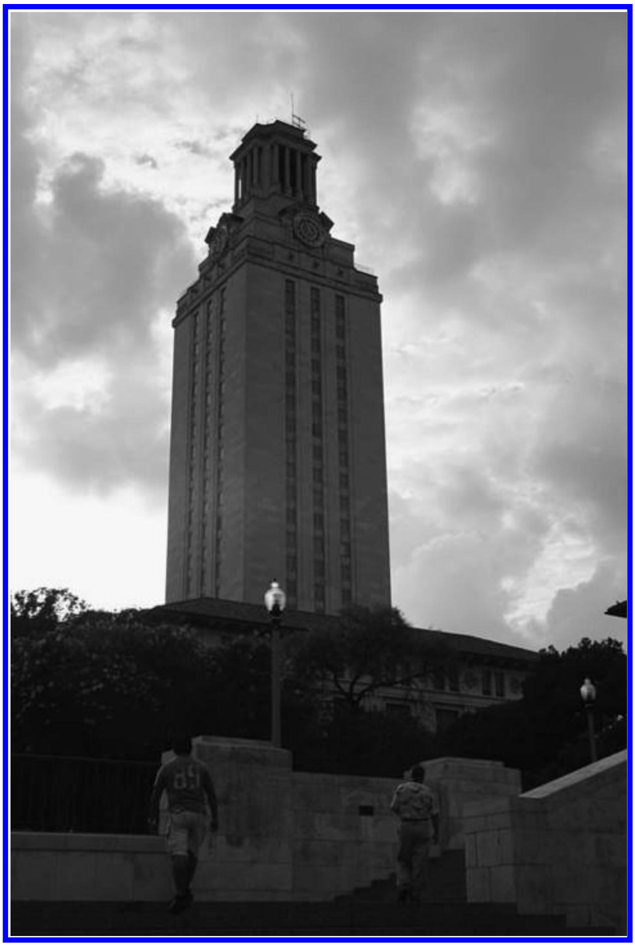

Figure 15.35 View of the tower from the quadrangle.

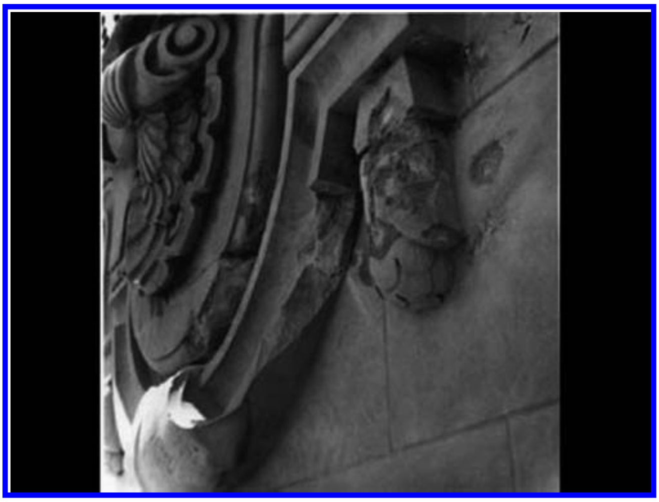

Figure 15.36 Bullet impacts at the top of the tower from shots fired up at the tower.

Figure 15.37 Whitman after Officers McCoy and Martinez emptied their weapons on him.

Why Is the Suspect Shot in the Back?

A question that frequently comes up in officer-involved shootings is “Why is the suspect shot in the back?” A study conducted by Dr. Bill Lewinski and published in the November/December 2000 issue of *Police Marksman* showed that, in many instances, an individual can turn around before an officer can react. This is particularly true when the officer’s weapon is holstered at the outset of the incident.

Dr. Lewinski’s studies have shown that the average officer requires about 1/3 of a second to fire a weapon from a psychologically set position with their finger already on the trigger. The ramifications of hesitation on an officer’s part can be devastating. Media attention on officer-involved shootings is at an all-time high, setting the stage for a deadly moment of hesitation by an officer in an otherwise fully justified use of lethal force. Dr. Lewinski describes a number of commonly encountered scenarios with armed suspects in which legitimate justification for use of lethal force is demonstrated by a suspect but by the time the officer is able to react, the suspect has turned and now presents his back as a target. The best solution to this dilemma may well lie with body cameras. Most departments welcome the deployment of these devices.

Another viable source of information for reconstructing officer-involved shootings is found with surveillance video cameras. Many large cities have installed these cameras

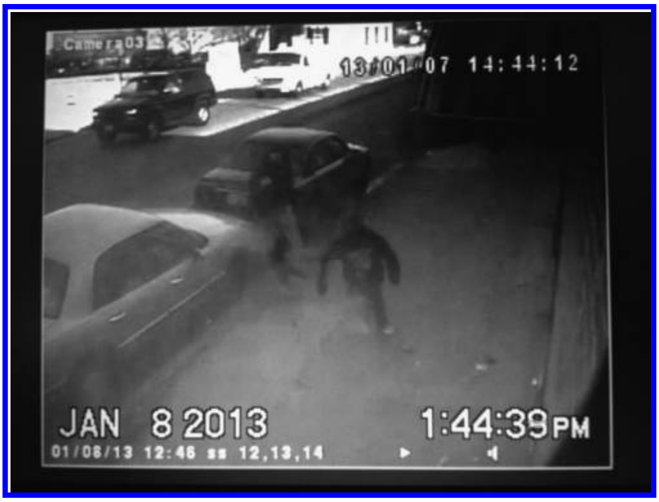
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Figure 15.38 Street cam 1.

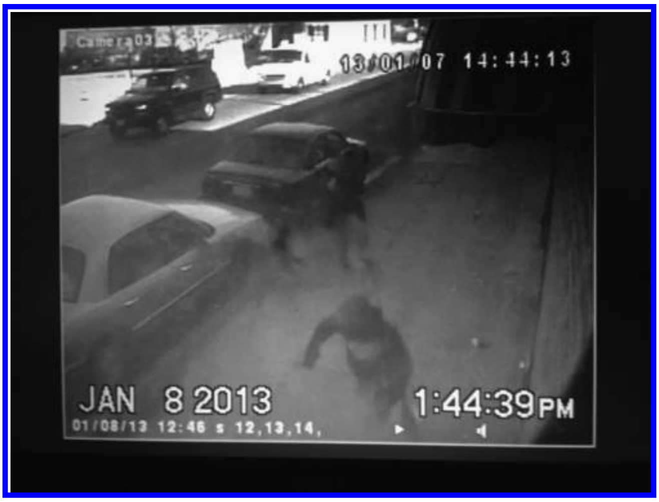
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Figure 15.39 Street cam 2.

and more and more use is being made of these devices in disputed cases. Examples of the images that can be produced from these cameras are shown in Figures 15.38 and 15.39.

Exercises

TRUE OR FALSE

1. Suicide by cop has a number of signs that officers and investigators should be familiar with.
2. Unintentional firing results from mechanical malfunction.
3. Accidental firing is a fairly common occurrence.
4. A barricaded individual is a likely candidate for suicide by cop.

5. Charles Whitman gave multiple indicators as to his suicide by cop intentions.
6. An officer can safely handle a suspect with one hand while holding a gun on the suspect with the other hand.
7. Tripping or being startled while holding a gun and having a finger on the trigger can result in unintentional discharge.
8. A lighter than normal trigger pull can contribute to unintentional discharge.
9. A police armorer is an appropriate individual to ask to carry out an examination for possible malfunction of an officer's weapon.
10. Officer's weapons do not need to be examined in a police shooting unless malfunction is expected.
11. All officers present at a shooting need to be sampled for GSR, even if there is no question as to who fired shots.
12. The loading status of officers' weapons needs to be determined as soon as possible during a shooting investigation.
13. Footwear impressions at a shooting scene need to be evaluated and compared to officers' footwear.
14. Cartridge case locations can be used to establish officers' positions as long as shot directionalities are known.
15. Officers' weapons may be turned into the armorer or crime laboratory by the officers themselves at some convenient time following a shooting incident they have been involved in.

Answers: (1) T, (2) F, (3) F, (4) T, (5) T, (6) F, (7) T, (8) T, (9) T, (10) F, (11) T, (12) T, (13) T, (14) T, (15) F.

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Case Analysis

16

The term "case analysis" refers to an overall assessment of the case with a goal of not only determining how a shooting incident took place but what the particular circumstances were leading up to the shooting.

The elements of case analyses include the following:

- Police investigative reports
- Crime laboratory reports (DNA, latent prints, gunshot residue [GSR], trace evidence, firearms and blood spatter pattern analysis as appropriate)
- Crime scene photographs, sketches, and diagrams
- Witness statements (including those made by participants)
- Autopsy reports (including autopsy photographs)
- Medical treatment records (when appropriate)
- Surveillance videos, police lapel/dash video recordings
- Police radio transmission transcripts associated with the incident
- Reenactment results (when appropriate)
- Telephone records (land and cellular) within the period of the incident
- Business/financial records (when appropriate)

General Considerations

Shooting incident reconstruction readily lends itself to a "holistic" approach—that is, all aspects of the events leading up to the shooting, as well as those that follow it, need to be considered in analyzing the case. Simply looking at the physical evidence alone may not allow the investigator to have the proper insight required to decipher the events of the shooting. The possible motivation for a shooting can sometimes shed light on how a shooting took place. Certainly knowing something about a person's medical history, financial status, and marital situation can assist in trying to distinguish between homicide and suicide (under either circumstance, a motive is required).

A common mistake that investigators make in trying to reconstruct shootings is to try to go "stop-action" or "frame by frame" through the shooting. A shooting incident is a dynamic event that frequently involves movement by the various persons involved. Shooting incidents often occur in a very brief span of time. A shooting the author reviewed involving two officers and one suspect that resulted in 48 shots being fired required an elapsed time of just more than 2 minutes, as an example. When multiple shots have been fired, trying to determine the shot order and the exact body positions for those involved as each shot was fired is often an impossibility and, many times, unnecessary.

Individuals, including officers, involved in shootings are in very high stress situations. Recollections as to number of shots fired, positions during the shooting, and the like are often unclear. A fairly common mistake made by witnesses in shootings is to transpose the position of the gun based on their visual perception and their own dominant hand. In other words, a person facing an individual who is holding a pistol in their left hand correctly perceives the weapon as being to their right. If the individual making the observation is right-hand dominant, that tends to further cultivate the notion that the weapon was in the shooter's right hand rather than the left hand.

A case that has been aired on a popular forensic television program a number of times over the past several years that involved an officer who claimed he shot a female resident in the bedroom of her home (the subject of a search warrant) because she refused to drop a gun she was holding in her right hand. Ultimately, criminal charges were filed against the officer. At trial, under cross-examination, the officer steadfastly continued to maintain that the woman (who he shot dead) had been holding the gun in her right hand. The woman's son testified that his mother was left-handed and hardly ever used her right hand for anything.

The defense tried to have their expert testify to the common misconception of officers who are facing an armed subject being biased toward their own hand dominance (i.e., if they are right-hand dominant they typically see others as right-hand dominant) and that predisposition being reinforced visually (as viewed face to face).

The prosecution successfully kept that testimony out of consideration by the jury by objecting to its relevance in the case at hand (i.e., there was no proof that it had occurred in the case at hand) and the judge sustaining the objection. The officer ultimately was convicted of murder in the case.

Few individuals ever accurately report the number of shots fired in a shooting incident they either witness or are involved in. The reason is undoubtedly attributable to the stress of the moment and the concentration on survival that is involved. Thus, it should come as no surprise when multiple individuals who are present at a shooting report varying numbers of shots fired, none of which are accurate.

Time frames associated with shooting incidents constitute another area that frequently gets misstated. Individuals may, for example, report hearing shots fired "seconds" apart when, in fact, they were all fired within a single second. Total elapsed time for a shooting may get reported as "several minutes" when the actual time involved was only a matter of seconds. The investigator must consider these reports but weigh them with other aspects of the case and recognize their propensity for inaccuracy.

One thing that an investigator can do to at least establish a minimum time for a particular firearm to fire a certain number of rounds is to consult published data regarding rates of fire and/or carry out controlled firing using the weapon in question and several shooters (in an attempt to minimize the human aspect). One source is Haag (2000). As a general rule of thumb, it is not uncommon for a trained marksman (e.g., an officer) firing a semiautomatic pistol to be able to fire 4–5 rounds per second.

A man is allegedly standing back in an alley between two buildings that are 40 feet apart. The man is believed to have had a semiautomatic Glock 9-mm pistol at the ready (i.e., loaded, in his hands, finger on the trigger with arms extended) as he waited for an oncoming motorcycle to appear in the 40-foot field of view (he was believed to have heard the approaching

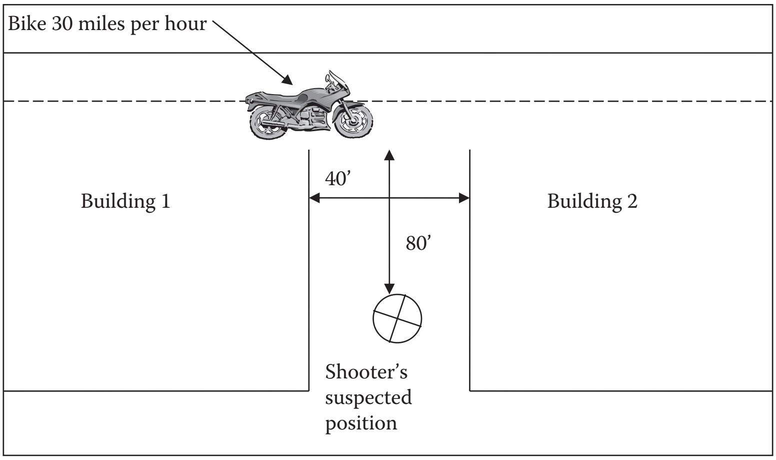

Figure 16.1 Scene diagram.

motorcycle because of its loud exhaust). A total of two shots are fired, one striking the gas tank and ricocheting off, and the second striking the motorcycle rider in the right temple and killing him. According to the police accident reconstruction unit, the drag marks left on the pavement indicate the motorcycle was traveling about 30 miles per hour.

No bullets are recovered, and no fired cartridge cases are found. The suspect, who was arrested some time later based on information supplied by a tipster, denies any complicity. His defense attorney challenges the ability of anyone to get off two shots with only 40 feet of "opportunity" at a motorcycle going approximately 30 miles per hour. How can this question be answered most simplistically? Figure 16.1 shows a scene diagram.

The simplest approach is to do a mathematical calculation as to how long (at a minimum) the motorcycle would have been in the 40-feet field of view, then compare the result to published values for rate of fire for a Model 17 Glock 9-mm semiautomatic pistol. The calculation would be done as follows: 30 miles per hour equals 44 feet per second. For the motorcycle to traverse the 40 feet span involved, we must divide 40 feet by 44 feet per second to yield the number of seconds required (simply use the units to determine whether to divide or multiply—feet divided by feet/second is the equivalent of feet × seconds/feet, wherein the feet cancel, leaving the unit "seconds"). Accordingly, the answer is 0.9 second. If we refer to Luke Haag's table (Haag 2009), we find that a Model 17 Glock 9-mm pistol has a cyclic rate of five rounds in 0.98 second. Because only two rounds were fired in the incident under study, it is clearly feasible, from a purely mathematical perspective at least, for the shots to have been fired by the suspect weapon within the allotted time frame.

The mental state and physiological condition of the individuals reporting shooting events must be ascertained and considered. Individuals who are under the influence of alcohol or other drugs at the time of a shooting must be considered as generally unreliable. Individuals who are mentally ill or disabled obviously cannot be relied on to provide valid information in a shooting incident and probably would not be allowed to testify in court anyway.

The physical condition of individuals involved in reporting any aspect of a shooting needs to be considered and evaluated. Questions relating to vision (e.g., wearing of glasses/contacts at the time) and hearing immediately come to mind and must be evaluated when considering the statements provided in shooting incidents. Admittedly, the evaluation of an individual's vision is much easier to establish than hearing acuity. A question that frequently comes up in officer-involved shootings is whether the officer could be heard announcing themselves as police. Structuring any sort of reliable test scenario is pretty difficult because of all the associated variables.

Shot Accounting

One of the most important aspects of on-site/off-site shooting reconstruction is shot accounting. This involves reconciling the number of fired cartridge cases, fired bullets, bullet holes (in inanimate objects), and bullet wounds with one another. The investigator should make every effort to do as much as possible to settle these issues before leaving the scene (i.e., make a thorough search for bullets/fragments and fired cartridge cases; Figure 16.2).

All weapons recovered at the scene need to be unloaded, and a loading diagram is prepared that shows the status as found as described in an earlier chapter (Figures 16.3 and 16.4). Ultimately, it will be necessary to establish the magazine capacity of all semiautomatic and automatic weapons involved in an effort to determine the maximum number of rounds that could have been fired (magazine capacity + chamber minus the total number of rounds remaining in the weapon = the maximum number of rounds that could have been fired). This, of course, assumes that no reloading was involved during the shooting. If additional magazines were used, obviously their contents would also have to be considered.

The autopsy report is used to determine the number of entry/exit wounds and the number of bullets recovered. Consideration for multiple wounds caused by a single bullet must be given when the wound count does not coincide with the shot count. Naturally, missed shots result in fewer wounds than shots fired (Figure 16.5).

In the case of fragmented bullets, the total weight of all fragments recovered can be compared to the weight of an intact bullet in order to estimate the number of bullets represented. In reviewing numerous shooting cases worked by various agencies over the years, the author has often experienced the perplexing situation of having no clue as to what

Figure 16.2 Determining the number of shots fired.

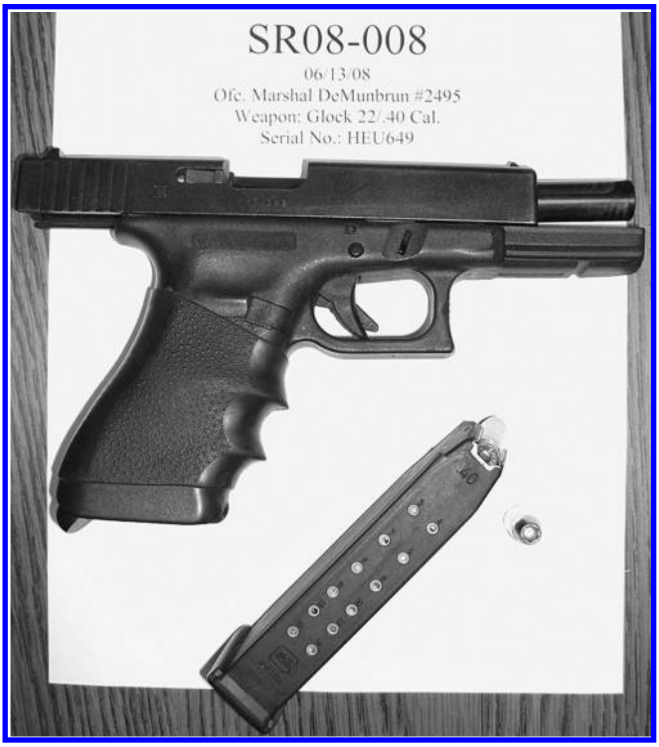
SR08-008
06/13/08
Ofc. Marshal DeMunbrun #2495
Weapon: Glock 22/.40 Cal.
Serial No.: HEU649

Figure 16.3 Officer's weapon showing magazine (as removed) and round from chamber.

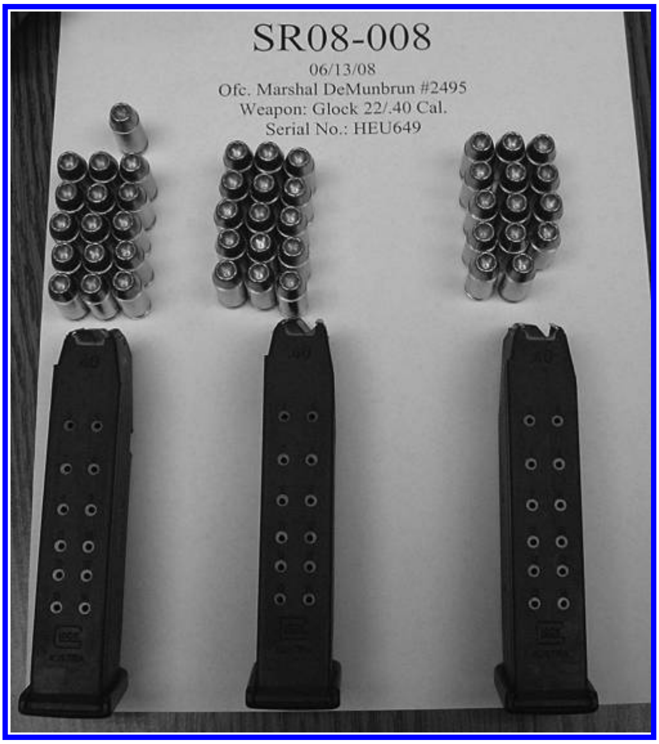
SR08-008
06/13/08
Ofc. Marshal DeMunbrun #2495
Weapon: Glock 22/.40 Cal.
Serial No.: HEU649

Figure 16.4 Officer's magazine contents (note the round from chamber—top left).

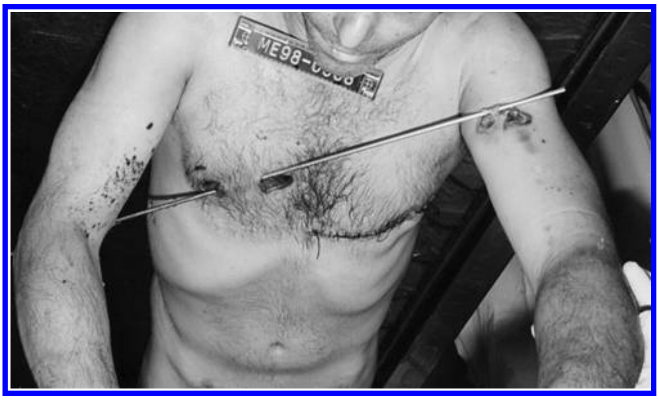

Figure 16.5 Autopsy photo showing probable trajectory.

the bullet evidence described in reports actually was. As presented in Chapter 1 (see also Appendix B), a favorite "catch-all" term used by many agencies is "projectile." By definition, a projectile is simply a body in motion. Thus, a projectile could be anything from a bullet to a Volkswagen flying through the air. A problem in communication results when scene investigators apply the term to various types of bullet fragments, such as jacket fragments or core fragments, and then use the same term to describe an intact bullet. The individual reading an evidence list is left with no idea as to what was collected.

As a way of getting everyone "on the same sheet of music," the following terminologies are once again suggested:

- Bullet—correct term for an intact and complete lead, copper, or jacketed/electroplated lead bullet
- Bullet fragment—correct term for a bullet that is not entirely intact owing to loss of some portion of the jacket and/or core/body (but still recognizable as a bullet)
- Bullet core—the inner lead portion of a jacketed bullet
- Bullet core fragment—a less-than-complete bullet core
- Bullet jacket—a complete steel, copper or brass bullet jacket without a core
- Bullet jacket fragment—a less-than-complete bullet jacket
- Metal fragment—the term that should be used when there is a question as to whether the item actually originated from a bullet jacket or core

The prefix "fired" is usually unnecessary, because it is assumed that all components are the product of firing. Figure 16.6 shows two fired bullets with their deformed noses being clear evidence of firing.

If investigators would all use these terms when describing bullet evidence, a great deal of confusion could be avoided. Attempts to describe bullet evidence using a variety of other terms can sometimes be downright humorous, if not ridiculous. In a case reviewed by the author several years ago, the following descriptions were used in a report documenting the bullet evidence:

Item 1—projectile
Item 2—projectile (intact)
Item 3—slug
Item 4—projectile (outer)

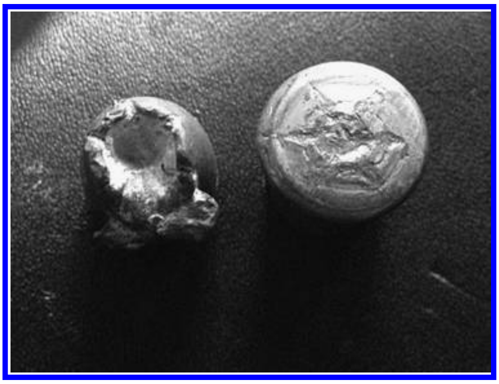

Figure 16.6 Two deformed bullets.

The actual evidence the investigator was attempting to describe was

Item 1—partial jacketed bullet
Item 2—jacketed bullet
Item 3—bullet core
Item 4—bullet jacket fragment

The confusion resulting from the use of such nondescript terms should be obvious. The bottom line for the investigator responsible for documenting bullet evidence is simple—call it what it is! In Figure 16.6, the bullet to the left is correctly referred to as a deformed bullet. The bullet in the image to the right has hit something hard straight on and, as a result, has a uniformly expanded nose but is also properly referred to as a deformed bullet. However, there is certainly nothing wrong with being more descriptive (e.g., regarding the bullet to the left: "a fired bullet with irregular nose damage" and the bullet to the right: "a fired bullet with uniform expansion"). Just not taking the tired, old "projectile" route will be a cause for celebration for many of us, however.

Generally, there is not as much confusion associated with descriptions of cartridge cases with the possible exception of shot shells. The most commonly used term for fired cartridge cases is "casing." This term is also sometimes used interchangeably for cartridge cases and shot shells. For the sake of clarity, it is recommended that fired cartridge cases be called just that and that fired shot shells be referred thusly as well. The use of terms such as projectile and casing has been firmly entrenched in police agencies for decades and continues to persist. As more investigators recognize the benefits of using clearly understandable terminology in referring to firearms evidence, perhaps these terms will slowly fade away.

Another problem that frequently rears its ugly head is the use of multiple designators for firearms evidence items. In the typical scenario, the crime scene investigator assigns a designator to evidence collected in the field, the medical examiner assigns a designator to ammunition components collected at autopsy, and the crime laboratory assigns its own designator to all the submitted items it receives for examination. When the laboratory report is issued, it sometimes appears as if the intent is to create utter confusion as to the source of the evidence as numbers appear that have no relevance to the original numbers assigned at the scene. To avoid such confusion, it is recommended that, if new designators are assigned to evidence, the original designators be included as parenthetical entries along with a description of the source.

Shot count

Bullets/fragments found at scene	5	(2 on floor, 3 in east wall)
Cartridge cases found at scene	9	(all on bedroom floor by door)
Entry wounds in victim	5	(3 bullets recovered at autopsy)
Exit wounds in victim	2	
Total shots believed fired	9	
Unaccounted for (missing) bullets	1	

Bullets

CSI #	ME #	LAB #	Source	Description	Result
EEH-1	ME-2	Q3	NE floor - BR	Jacketed bullet	ID as fired from Q8

(Abbreviated)

Cartridge cases

CSI #	ME #	LAB #	Source	Description	Result
EEH-8	–	Q12	BR floor	Fed 40 S&W	ID as fired in Q8

(Abbreviated)

Figure 16.7 Shot accounting chart.

As an example, suppose that the pathologist recovers a bullet that is designated "gunshot wound #4—left anterior forearm." Further suppose that an investigator receives this bullet for transport to the crime laboratory and lists it on the evidence submission form as "item 2—bullet from autopsy." When the firearms unit gets it, it is then assigned the designator "Q1 bullet."

When the firearms report is issued, the statement "The Q1 bullet was identified as having been fired from the Q7 pistol" is included. This is going to be quite clear to all concerned if there is only one shot involved. But what if there are multiple shots involved? This is the type of situation where confusion often results because of the reassignment of evidence designators. The recommended remedy is to use the following type verbiage: "The Q1 bullet (M.E. #4—from left anterior forearm) was identified as having been fired from the Q7 pistol." This makes it perfectly clear as to what is being referred to.

It is frequently useful for the investigator to produce charts that summarize all the ammunition component evidence. These charts can be presented in court to assist jurors in understanding how many shots were fired. An example is shown in Figure 16.7 (bullet/cartridge case tables have been abbreviated). In this example, one bullet was unaccounted for. These types of charts make it easy to grasp the interrelationships of the ammunition component evidence. All evidence designators that have been used should be included for clarity.

Recognizing Staged/Misrepresented Crime Scenes

Staged crime scenes are those in which evidence has been altered and/or the scene has been rearranged in some matter. Misrepresented crime scenes are those in which persons give false statements as to the events involved. There are a number of indicators of possible staged/misrepresented crime scenes that the investigator should be on the alert for. These include the following:

- Postmortem lividity in the wrong location
- Dried/coagulated blood that should not be so
- Bloodstains going in the wrong direction
- Blood voids where blood should be
- Bloodstains where blood should not be
- Fired cartridge cases missing or out of place
- Bullet trajectories that are inconsistent with stated shooter positions
- Weapons in unusual positions
- GSR results that are inconsistent with stated shooter positions
- Bullet hole appearance that is inconsistent with stated muzzle-to-target distance
- Trace evidence results that are inconsistent with stated shooter positions
- Latent print/DNA examination results that are contrary to predicted/expected results

Postmortem lividity can indicate the repositioning of a body. In a case the author was involved in, a woman was found shot to death by officers who had been called to the scene by her boyfriend. The man claimed to have called 911 immediately after seeing his girlfriend "shoot herself" behind her right ear with a .44 Magnum revolver. He stated that she did so while standing in the bedroom closet facing out toward him. He further stated that after she fell to the floor facedown, he did not move her before the officers' arrival. The officers immediately noticed postmortem lividity on her buttocks (she was clad in a thong) as she lay on her stomach. Because the officers had arrived within 8 minutes of the 911 call, there should not have been any lividity present. Regardless of the time length involved, lividity on her buttocks was a clear indication that she had been on her back for a sufficient length of time for lividity to develop and she had then been subsequently moved (Figure 16.8).

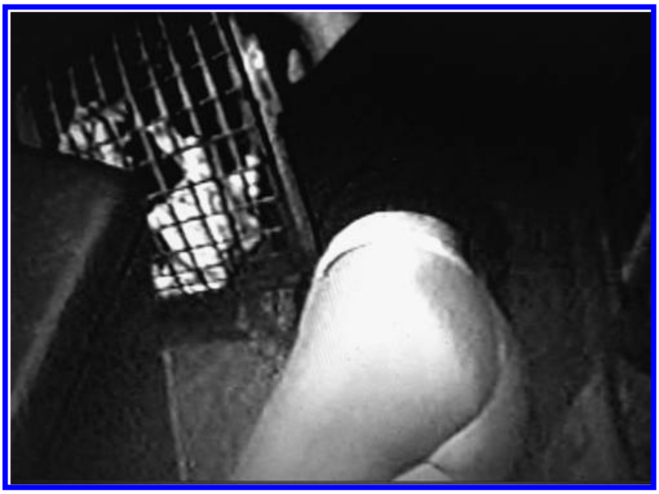

Figure 16.8 Lividity on buttocks.

Missing or "displaced" cartridge cases can sometimes reveal that the scene has either been altered or that the events have been misrepresented. Conversely, it is often unreasonable for someone to reposition cartridge cases in a scene for the purpose of scene staging. Anyone who has tried to collect their fired cartridge cases from the ground at an outdoor range knows that it is often tough to locate them, to say nothing of trying to do so at night or in tall grass.

In general, finding things in a crime scene that appear to be out of place and/or out of context may be a sign of a staged crime scene. The case study at the end of this section will present several unusual examples of things being out of place. The investigator must keep a sharp eye out for these types of occurrences. Recognizing the possible implications of these subtleties is what separates the real scene investigators from everyone else.

When weapons appear to be out of place, given the purported events of a shooting, one must be very certain before eliminating a particular position as being possible. The author has seen weapons wind up in seemingly suspicious locations only to ascertain that no foul play or staging of the scene was involved. In one shooting incident in which there was a question as to whether a man had shot himself while seated in the driver seat of his vehicle, the weapon was found under the driver seat. The shot was a contact shot to the right temple, the decedent was right-handed, and the weapon belonged to him. The vehicle was parked on a dirt road and the roadway and ground in the area was very soft. No footwear impressions or tire impressions were observed leaving the scene.

A series of drop tests were conducted using a similar vehicle. The idea was to simulate the decedent shooting himself and then allowing the weapon to fall out of his hand. It was found that, owing to the presence of a center console in the vehicle, the weapon could occasionally wind up under the front edge of the seat. Any possible movement of the decedent's feet could have conceivably pushed the gun further back as it had been found.

No fingerprints were found on the gun. Although there was blood spatter on the muzzle of the weapon, there was none on the decedent's right hand. However, it is well known that blood spatter appears on the hand in such shootings less than half the time. As is sometimes the case, no clear answer was forthcoming as far as the physical evidence was concerned.

In conclusion, when crime scenes appear to have been altered, the first thing to ascertain is whether the perceived change(s) to the scene are intentional or unintentional (on the part of the suspect). The most commonly encountered alterations to scenes in the author's experience have resulted from first officers to scenes, emergency medical technicians, and others involved with life-saving efforts. Bodies have been repositioned, bloodstains produced, trace evidence transferred, and cartridge cases and bullets moved about all unintentionally. It is, therefore, always a good idea to interview all the first responders to a shooting scene regarding what took place before the arrival of the investigators.

In a case that really brings the point home, the author spent several hours mapping cartridge case locations on a roadway in a police shootout only to learn that a helicopter had set down in the scene in order to transport the wounded defendant to a distant hospital. A video camera inside a police unit had captured the landing on tape. When the tape was reviewed, the wash from the helicopter could be seen causing cartridge cases to be blown about the scene as if a giant egg beater had been used.

Off-Scene Analysis of Crime Scene Data

There are a number of steps relating to the reconstruction of a shooting that are best completed off-scene, subsequent to the requisite on-scene documentation. These would include the following:

- Shot accounting
- Trajectory analysis
- Cartridge case location analysis

As previously discussed, shot accounting involves reconciling the number of fired cartridge cases with the number of recovered bullets/bullet fragments, the number of bullet impacts/entries to/in inanimate objects, and the number of entry wounds in victims. Although this can obviously be accomplished at the scene whenever only one or two shots are involved, more complex shootings (i.e., those involving multiple shots, multiple shooters, and/or multiple victims) are frequently better dealt with back at the office after examining all the evidence. This is particularly necessary when many or all of the bullets involved fragmented. The fragments need to be examined for trace evidence, weighed, and checked for physical matches (i.e., jigsaw puzzle fits between fragments) in order to be able to estimate the total number of bullets represented and their source, if possible. A word of caution regarding using combined fragment weight: It is sometimes better to use recognizable bullet features, such as bullet bases, to determine the total number of bullets represented. This is because the combined fragment weight could be less than the total number of bullets represented morphologically.

The linear and angular components measured for each bullet trajectory need to be incorporated into scale diagrams for evaluation as to shooter position. Two views need to be prepared unless three-dimensional views can be produced either using computerized animation or scale models. The two views required are: (1) side (profile) view and (2) top (overhead) view. Photographic images may be used to accomplish the same things if feasible. Once these diagrams are prepared, scenario evaluation can begin. Examples of the two "must-have" perspectives are shown in Figures 16.9 and 16.10.

Cartridge case analysis need only be done using the top perspective unless there is a potential issue concerning obstacles (i.e., low hanging structures/objects) that must be

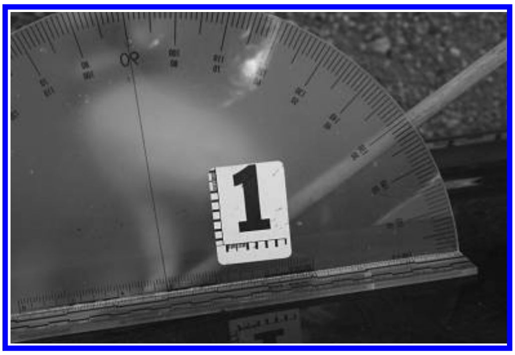

Figure 16.9 Side view of trajectory.

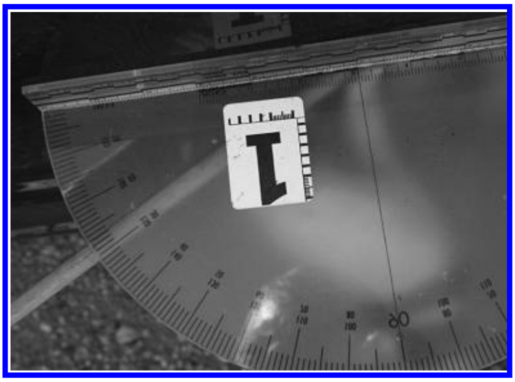

Figure 16.10 Overhead view of trajectory.

addressed. As discussed in the section on cartridge case analysis, the direction of fire must be known and the cartridge case locations must be legitimate in order to be able to make any meaningful statements about probable shooter position. Scale diagrams can sometimes provide useful insight into the reliability of witness statements concerning shootings.

Homicide versus Suicide Issues

The question of homicide versus suicide frequently comes up at shooting scenes. There are a few misconceptions and misunderstandings among some investigators that have persisted through the years. These include the following issues.

Common Misconceptions

- If there is no GSR on the hands of the victim, it is a homicide.
- Finding GSR on the back of the hand but not the palm means suicide, while the reverse situation (GSR on the palm but not the back of the hand) means homicide.
- No blood spatter on the hands of the victim of a contact headshot indicates it is homicide.
- No suicide note indicates homicide.
- A female who suffers a head shot was probably murdered because women never shoot themselves in the head.
- Multiple gunshot wounds means homicide.
- A shot other than to the head by a male is suggestive of homicide.

Probably the best response that can be given to all of these statements is the phrase "Absence of evidence is not evidence of absence." Not finding something can never be taken as absolute proof of a particular occurrence. Or, to put it another way, a negative finding cannot be used to make a positive statement.

A negative test result for GSR on the hands of a suicide victim can be caused by such things as faulty sampling technique, analytical error (e.g., poor technique, switching samples), failure of the weapon to produce detectable residue, or environmental factors both during and after the shooting. Likewise, positive results for GSR on one or the other surfaces of the hand can depend on how the sampling was done as well as other factors such as postmortem handling.

Back spatter from a contact wound to the head with a large caliber weapon such as a 9-mm or .38 Special can certainly be expected. Studies by Vincent Di Maio of the Bexar County Institute of Forensic Science in San Antonio, Texas, indicate that most of the time no visible blood spatter is produced on the gun hand, however. The investigator should carefully inspect the weapon for blood spatter consistent with a gunshot. If it is widely distributed over the surfaces of the gun, not finding any blood on the hands would certainly raise a question. Even in this kind of situation, however, the only conclusion that is scientifically valid is that "No blood was found."

Not finding a suicide note in a case of self-inflicted gunshot death is the norm rather than the exception. Suicide notes are found in only about a third of the documented suicides. On the other hand, finding a suicide note would certainly necessitate verification of its authenticity.

The body location choice for a self-inflicted gunshot often becomes a subject for debate. While it is certainly true that men most frequently select the head rather than the body and vice versa for women, the contrary certainly does occur, albeit less frequently. The same can be said for a right-hand dominant individual who is found with a contact wound to the left temple or a left-hand dominant individual with a contact wound to the right temple. It happens! Certainly, one should look carefully at all aspects of the incident, but "using the wrong hand" does not, in and of itself, indicate homicide.

The author has seen a number of cases over the years in which there were multiple shots fired by an individual intent on doing themselves in. It is not uncommon for the individual to give themselves a grazing wound to the head as a result of flinching at the last moment or because the weapon was held at too steep an angle. This often precipitates an additional shot to "finish the job." Other cases have included multiple body shots. Even self-inflicted shots to the back of the head are not entirely unheard of as was discussed in the case study of Chapter 14. In any event, the investigator should be cautious about declaring that homicide has to be involved based merely on multiple shots having been inflicted.

Participant Information to Obtain

There are a number of things to find out about participants in shooting incidents in the interest of reconstruction. While the previous section might seem to have downplayed the importance of hand dominance, this is still something that needs to be considered. Other physical factors of importance include height, weight, hearing acuity, and vision. These are summarized in the following list. The need for some of these for shooting reconstruction purposes will vary with the circumstances involved.

Participant information that may be of importance:

- Dominant hand
- Height
- Weight
- Visual acuity
- Hearing acuity
- Existence of physical limitations
- Shoe size

- Waist measurement
- Arm length
- Weapon position (height of above ground, elevation of muzzle, cant to left or right)
- Inseam length
- Neck size
- Hat size

The majority of these features will be especially important when reenactment will be carried out (live or animated). Weapon position descriptions can most often be established in officer-involved shootings because officers typically have an established shooting stance. Gang members may use the "gangsta" sideways orientation of handguns and be able to confirm that. Otherwise, this information may amount to more speculation than anything else. In any situation, the likelihood of one scenario, as opposed to some other scenario, may well rest with one of these physical factors.

Things such as hearing and vision become especially important when witnesses are professing to have seen or heard certain things leading up to and during shootings. This is especially true in officer-involved shootings, as discussed in Chapter 15, where questions typically arise as to the justification for use of lethal force based on the officer's perception of threat from a would-be assailant or whether the officer properly identified himself. Establishing visual acuity is such situations usually requires subpoenaing medical records and establishing if the witness requires corrective lenses and, if so, were they in place at the time. Establishing hearing acuity is usually best accomplished by carrying out hearing tests on the individual as soon as possible after the shooting. However, as also mentioned in Chapter 15, it is very difficult to construct a meaningful test related to sound because of the many variables typically involved.

Shots Fired into Vehicles

The analysis of shots fired into vehicles (Figure 16.11) is entirely dependent on proper documentation of bullet trajectories in the vehicles. To begin with, the length, width, and height

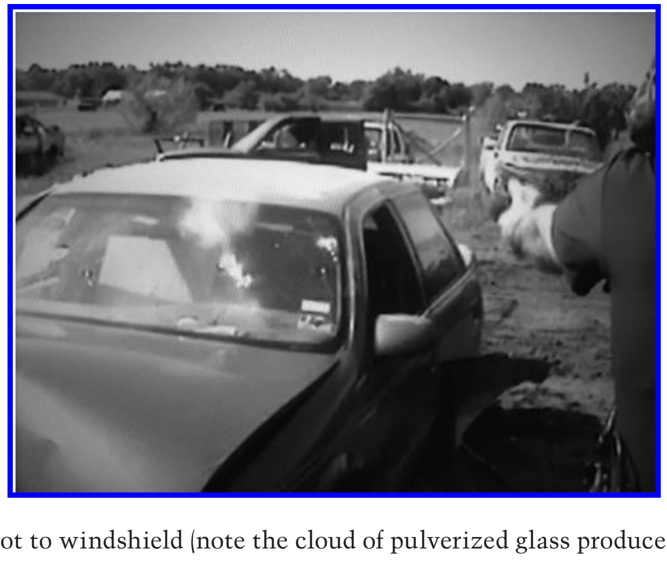

Figure 16.11 Shot to windshield (note the cloud of pulverized glass produced).

of the vehicle need to be measured along with any other measurements of importance (e.g., the windshield, the door openings, and the window openings). Although it is possible to obtain these measurements from the manufacturer, direct measurement eliminates questions about such things as different sized tires, for example.

As with all inanimate objects of suitable thickness/construction, the *x*, *y* linear coordinates and the *x*, *y* angular coordinates need to be carefully determined. A convenient standard reference point, such as the vertical plane of the rear of the vehicle, needs to be established and all the horizontal (*x*) linear measurements referenced to that point. The ground is typically used for the vertical (*y*) linear measurements. If one or more tires are flat, and it can be determined that the tire(s) became flat after the shots into the vehicle body, the vehicle must be leveled to its approximate original height before the vertical (*y*) measurements are taken. Otherwise, the vertical (*y*) measurement must be taken both ways (level and with deflated tire(s) on the ground). The same applies to the *x*, *y* angular measurements because a flat tire can produce a different apparent vertical angle than a fully inflated tire. Figures 16.12 and 16.13 illustrate the *x* and *y* angles.

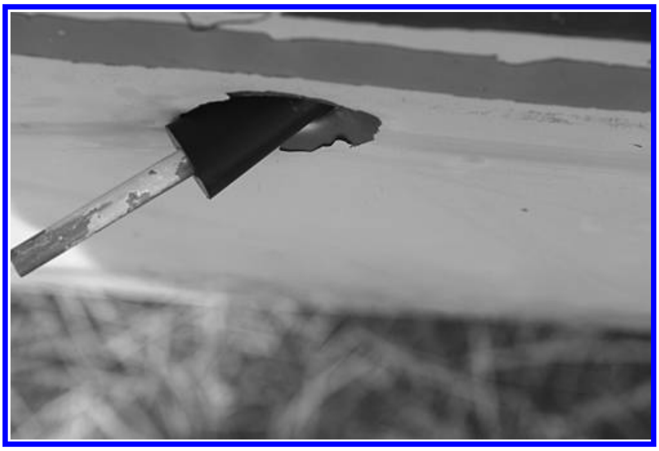

Figure 16.12 Overhead view of trajectory in a truck bed.

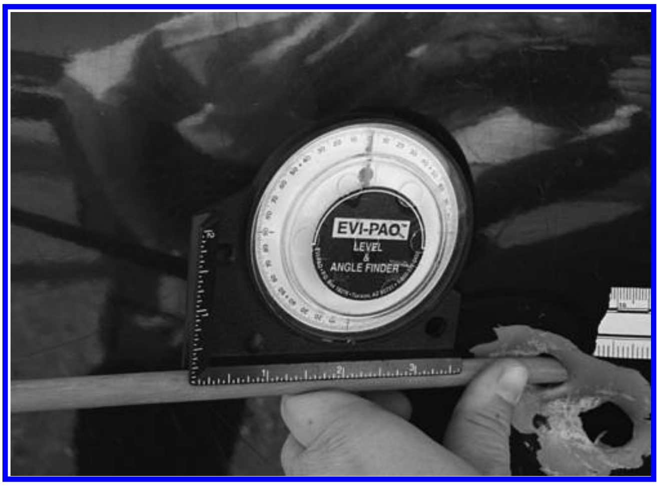

Figure 16.13 Side view of trajectory into a car body panel.

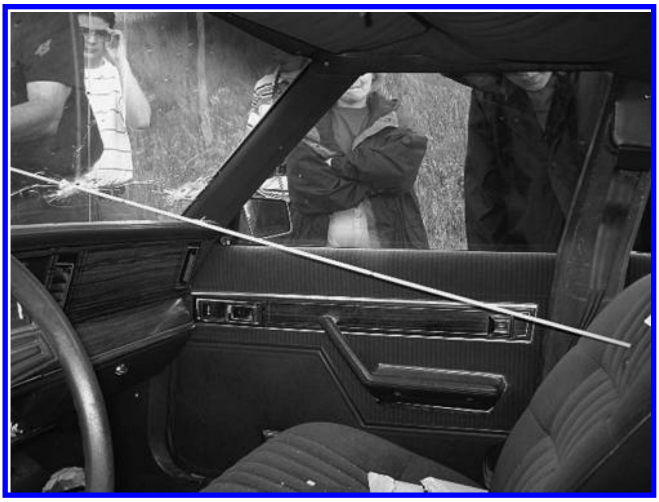

Figure 16.14 Shot through windshield.

All of the various linear and angular measurements should be referenced to imaginary vertical or horizontal planes, as appropriate. As already stated, one example would be the plane of the rear of the vehicle. This is important because few vehicles have flat body/window surfaces. It is also extremely important to make a sketch that references the way in which the angle was determined. An example of how to measure the vertical (*y*) angle of a trajectory rod passed through a bullet hole in a windshield is shown in Figure 16.14. A simple sketch or notation as to exactly what angle is being recorded should appear in the examiner's note. Simply recording "$y = 23°$," for example, can easily become meaningless weeks, months, and, especially, years later when trying to ascertain what was actually measured as discussed in an earlier chapter. Of course a photograph is going to be taken but, as when one is aboard an aircraft, having redundant systems is a good thing!

It is also important to determine the angle of inclination of windshields, and rear and side windows when bullet holes are present. That is easily accomplished with the angle gauge.

The following summary of the various special considerations associated with the documentation of bullet holes in vehicles should be used as a checklist by the investigator/examiner responsible for collecting and analyzing the data.

Vehicle Bullet Hole Documentation and Trajectory Analysis

1. Measure and record the general vehicle dimensions (overall length, width, and height).
2. Measure and record specific vehicle dimensions (door/window openings, etc.).
3. Measure and record angles of inclination of windshield, rear window, and/or side windows if perforated by bullets (this is easily accomplished using an angle gauge).
4. If one or more tires are deflated, determine the need to level the vehicle for purposes of taking trajectory rod measurements.

5. Determine the x, y linear positions of the bullet holes (x should be determined relative to some convenient fixed point such as the plane of the front or the rear of the vehicle; y is typically the height above the ground).
6. Insert trajectory rods into bullet holes (properly orient rods as described in Chapter 6) and determine the x, y angular coordinates.
7. Document the trajectory rod positions with overhead and side (profile) view photographs.
8. Prepare scale drawings (e.g., CAD, 3-D laser scans) based on the linear and angular measurements made for the bullet holes.
9. Analyze the feasibility of various shooter positions based on the scale drawings and involved person information obtained.
10. Conduct reenactments/testing for the purpose of confirming or refuting hypotheses developed.

By using this methodical and detailed approach, the investigator will often be able to include certain scenarios and exclude others. Moreover, the shots into the vehicle may be appropriately visualized by all interested parties. The additional use of three-dimensional diagrams may add to the reviewer's perspective of the shooting.

General Case Analysis Examples

Case 1. Accidental Shooting or Homicide?

A police detective returned home from a tanning salon appointment to find his wife slumped forward on their bed dead of a gunshot wound to the chest. A Glock 9-mm pistol, along with a towel, was lying next to her on top of several pieces of newspaper. An open gun cleaning kit was nearby. The detective claimed he had laid her back on the bed, called 911, and began CPR. The first responders found her body as shown in Figures 16.15 through 16.18.

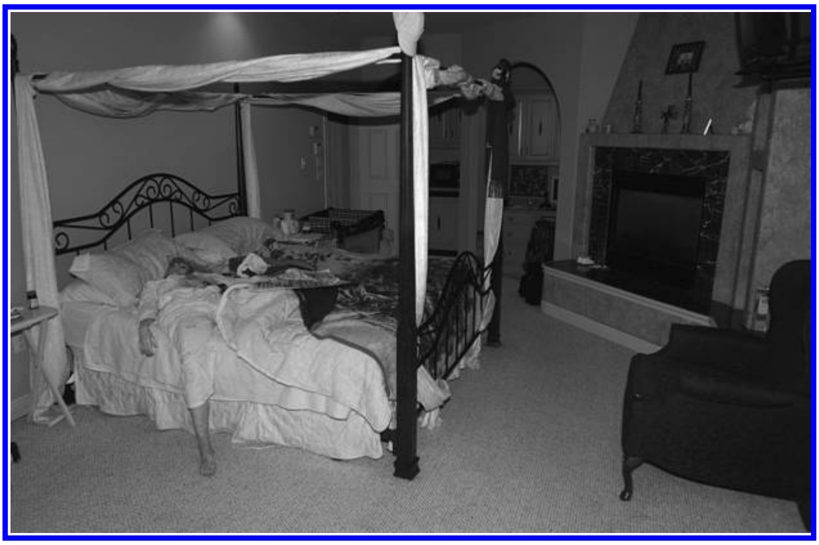

Figure 16.15 The body as found by first responders.

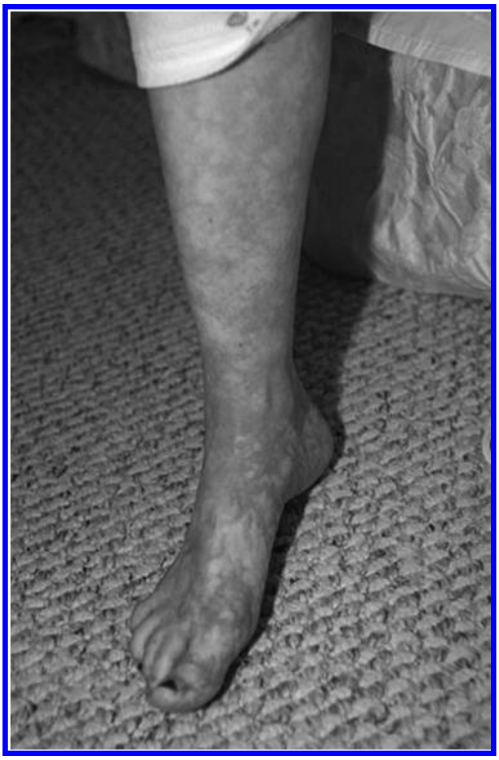

Figure 16.16 Condition of the right foot as noted by first responders.

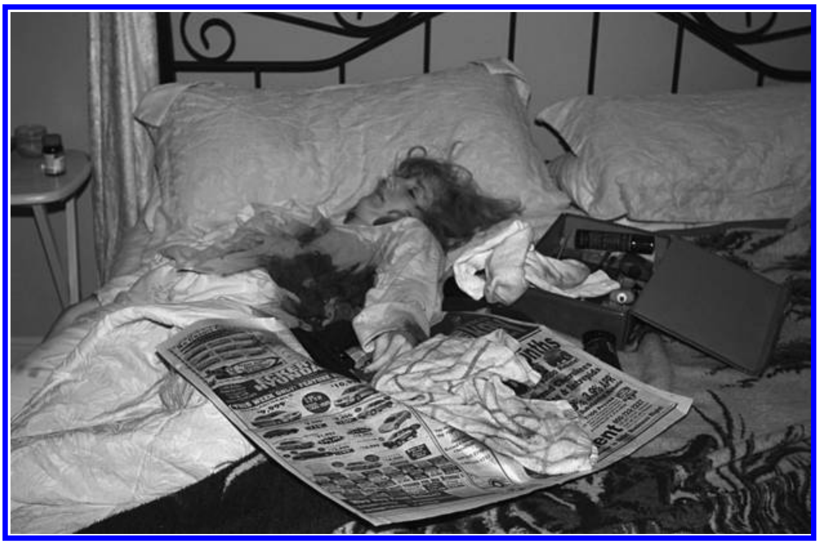

Figure 16.17 Firearm and cleaning materials.

When fellow detectives from his department arrived, the detective told them he had unloaded and started to clean his service pistol (the Glock model 17 on the bed) but had suddenly remembered that he had a tanning appointment at a nearby salon (approximately 10 minutes away). He stated his wife had offered to clean the gun for him while he went to the tanning salon but he told her to just leave it on the bed and he would clean the gun

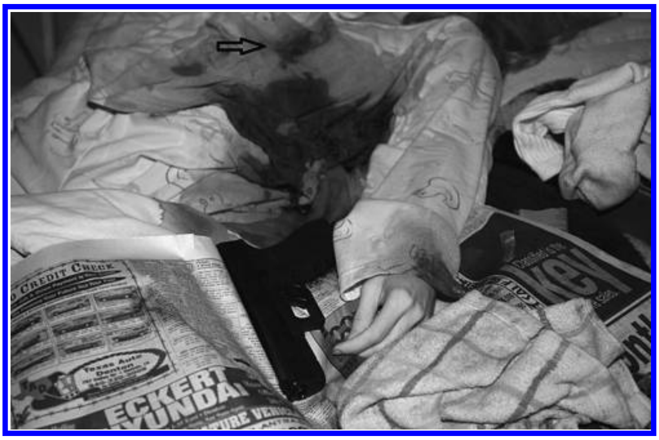

Figure 16.18 Bloodstains on nightgown (soot deposit around entry hole near top of image).

upon his return within the hour. He explained that the reason he had started to clean the gun was because he intended to go shooting at the police range the next day. He told his fellow detectives that he had no idea why she might shoot herself or how it could have happened accidentally. He said he had left the gun unloaded, but there was a live round in the chamber and rounds in the magazine when scene investigators took it into evidence.

Let us stop the narrative and see what initial impressions and questions an investigator may have formed. Read through the following discussion points and determine what, if any, significance there may be to the issues raised.

- Isn't it a bit unusual to be cleaning a gun PRIOR to going shooting?
- What was the wife's level of familiarity with the gun? (Had she ever cleaned it before? Had she ever loaded it before? Had she ever fired it before?)
- Isn't it a bit unusual to be cleaning a gun on the bed?
- Was there any evidence that the gun had been cleaned before the fatal shot?
- What was the round count for the gun (i.e., we know a round was found in the chamber, but how many were in the magazine)?
- Isn't there a piece of evidence missing (at least not mentioned yet)?
- How should the investigation of this incident have been handled?

Let us start by answering the last question. This incident should have been handled as a homicide and the investigation structured accordingly. That would entail each of the following being done:

1. Take a statement from the detective at the scene and follow up with a statement at the police headquarters later.
2. Perform a GSR test on the detective (even though he handled the gun before leaving, he had presumably showered after the tanning session).
3. Collect the detective's clothing and submit for latent blood testing.
4. Check the detective's vehicle for blood (steering wheel, door handle, seat belt, gear shift, brake/accelerator pedal).
5. Examine the residence for latent prints (possible intruder) and footwear impressions (outside in flower beds, etc.).

6. Canvass the neighbors for possible persons seen at the residence and time sound of shot might have been heard.
7. Request "touch" DNA on the gun trigger and grips as well as the magazine and contents.
8. Have the gun examined to attempt to determine whether it had been cleaned prior to firing.
9. Document the round count of the gun.
10. Locate the fired cartridge case (the answer to the next to last question above) and document its location (photographically and by taking measurements).
11. Photographically document the exterior and interior of the residence.
12. Check the cleaning kit for signs of use and for touch DNA and latent fingerprints.
13. Examine the contents of all trash cans.
14. Examine the washer/dryer for signs of recent use.
15. Examine the house for medications/drugs.

Which of these examinations do you suppose were done in this case? Unfortunately, only numbers 8 (examination of the cleaning status of the gun), 10 (location of the fired cartridge case), and 12 (check of the cleaning kit) were addressed. That was because the case was not handled as a homicide from the start, primarily because the detective was "one of us."

The results of the three examinations that were done are rather interesting.

In item 8, the Glock pistol was described as being "dripping wet" with solvent by an investigator. It was also noted that there were several "greasy" areas visible on the newspaper under the gun and cleaning materials. Figures 16.19 and 16.20 illustrate the location and condition of the pistol as found at the scene.

In item 10, the missing fired cartridge case was eventually found inside a fold of the bedspread *under* the cleaning kit box. That clearly raises significant question as to the time of placement of the cleaning kit relative to the time of discharge of the gun.

In item 12, the cleaning kit consisted of several rags, a pair of white socks, and some well-worn brushes and rods, all of which showed no sign of recent use. Also present was a can of Break-Free™ solvent and an empty can of gun oil. A partial print in apparent blood was present on the side of the can (Figures 16.21 and 16.22).

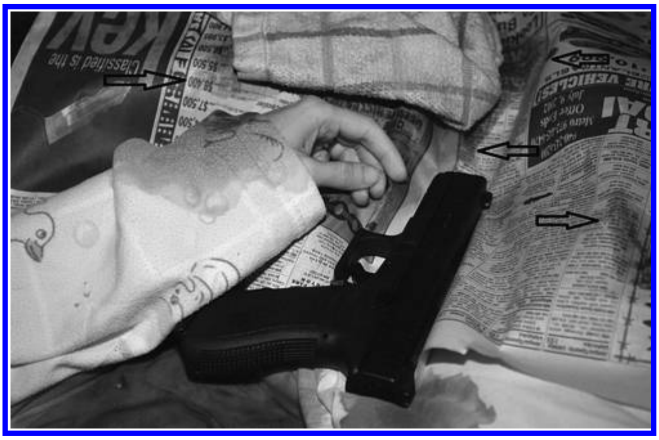

Figure 16.19 Glock model 17 9-mm pistol (arrows mark grease-stained areas).

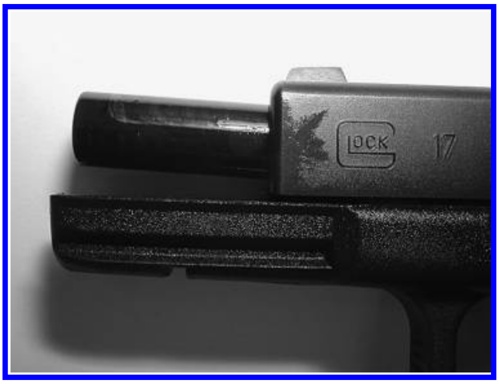

Figure 16.20 Excessive solvent present on the pistol.

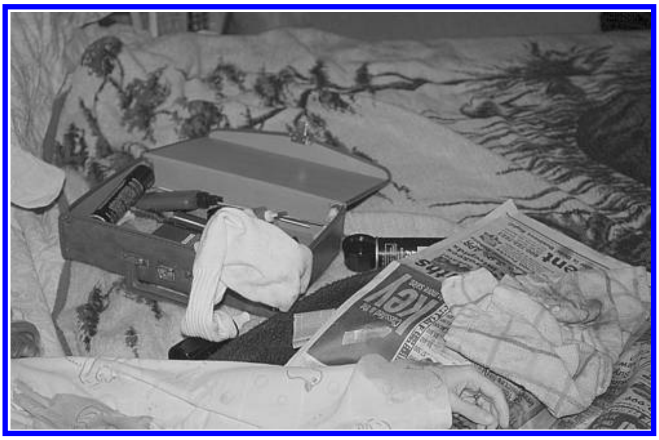

Figure 16.21 Cleaning materials as found by investigators (fired cartridge case was under the box at top left).

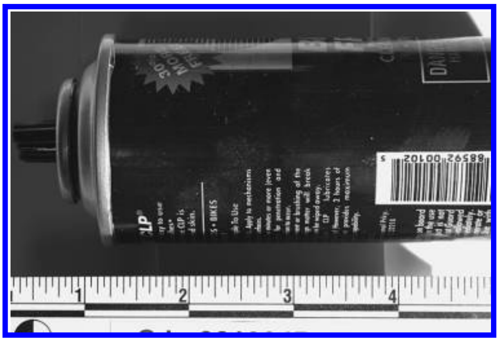

Figure 16.22 Break-Free solvent with partial fingerprint in blood.

Chemical analysis of the residue on the newspaper and the gun showed it to be consistent with Break-Free solvent. A laboratory examination of the victim's pajama top failed to show the presence of the solvent. Similar results were obtained on swabs taken from the hands of the deceased. A similar gun was subjected to being "hosed down" with Break-Free solvent and then fired in an effort to establish whether the solvent had been applied before or after the fatal shot. The results of this testing are shown in Figures 16.23 and 16.24.

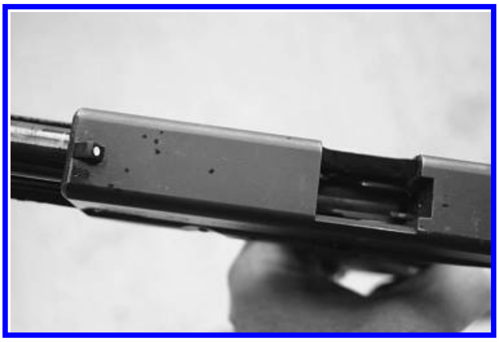

Figure 16.23 Specks of solvent produced by firing with excessive solvent present on the outer gun surfaces.

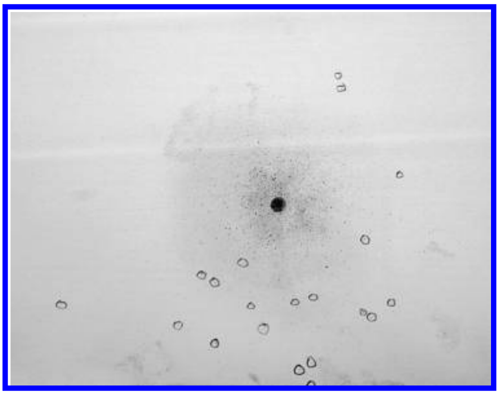

Figure 16.24 Test panel produced by firing from 4 inches away with excessive solvent present on outer surfaces of gun.

Break-Free solvent residue left on the test panel by firing was not found on the pajama top of the deceased (or on the bed clothes or items on top of the bedspread). Likewise, the outer surfaces of the incident pistol had no specks of Break-Free solvent residue as received. This was all consistent with the Break-Free solvent having been applied *after* the fatal shot was fired.

At this point, in spite of not having done all the appropriate investigations, the agency had some pretty powerful positive evidence (the location of the fired cartridge case) and some pretty powerful negative evidence (the lack of Break-Free solvent residue where it should have been). Positive evidence is always preferable to negative evidence, but the negative evidence was welcome at this point. There was, however, more positive evidence in the case. The partial print in blood on the Break-Free can was not identifiable but the blood was consistent with that of the deceased. This meant that it was deposited after blood was shed. The question as to when it was deposited (e.g., at some earlier time) would still be an issue. Had the detective been interviewed concerning whether his wife had ever used the cleaning kit before might have helped validate that the blood was contemporaneous with the shooting.

Other blood present that was of significance was a tiny spatter showing directionality that was inconsistent with a self-inflicted gunshot (Figure 16.25).

Also noted on hand was a possible gunpowder particle. The particle was not collected, so no confirmation was possible. Additionally, bloodstains on the undersurface of the

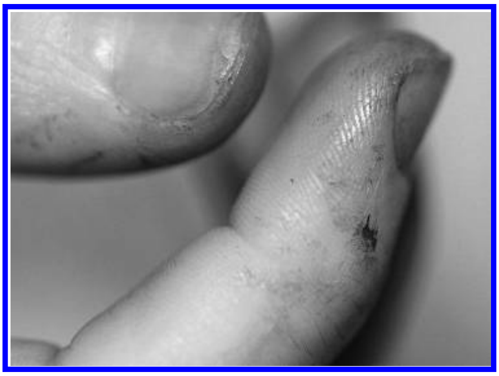

Figure 16.25 **(See color insert.)** Bloodstain showing directionality (toward the finger tip).

newspaper were consistent with the blood having already been on the bedclothes when the paper was laid down on top of it (Figures 16.26 and 16.27).

In an interesting twist, the detective was originally indicted but never taken to trial because of a claim by the then district attorney that the medical examiner had ruled the death a suicide. Some 7 years later, under a new district attorney, the case was reopened, a new indictment was issued, and the detective was brought to trial at last. The detective

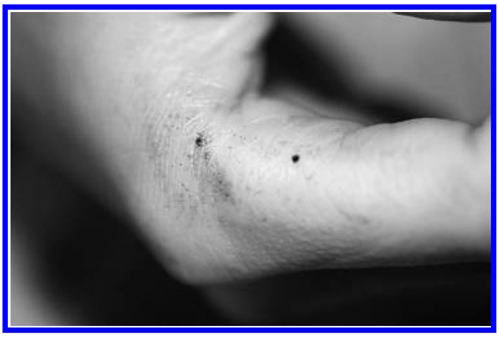

Figure 16.26 **(See color insert.)** Possible gunpowder particle on hand.

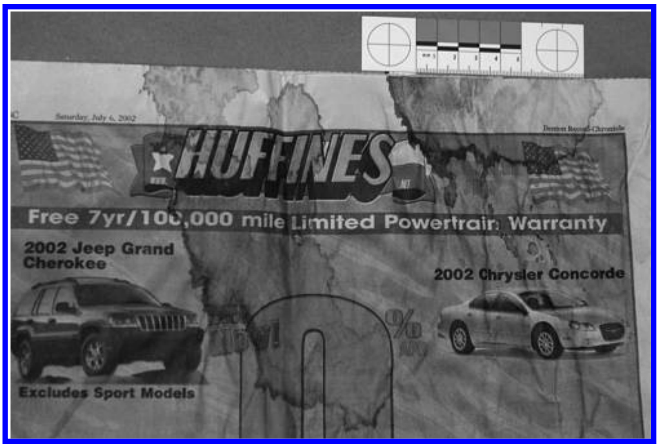
HUFFINES
Free 7yr/100,000 mile Limited Powertrain Warranty
2002 Jeep Grand Cherokee
2002 Chrysler Concorde
Excludes Sport Models

Figure 16.27 Blood on undersurface of newspaper showing that blood was present before paper was placed over it.

was convicted based in large part on the evidence presented here; however, at trial it was revealed that he had been having an affair at the time with a fellow female police officer who testified that they had sexual relations the evening after the death of his wife.

The detective received a 45-year sentence for the murder (upheld upon appeal).

This case serves as a reminder of the need to handle each case according to standard procedures and not take shortcuts or give special dispensations regardless of personal relationships. A factor in the case that was visible in the first two case images shown (Figures 16.15 and 16.16) was the lividity of the right foot of the decedent. Given the minimum time lapse from the detective leaving the house, having the tanning session, returning home, and the first responder arriving (approximately 45 minutes total), the visible lividity reported by the first responder is questionable (i.e., it suggests that she may have been dead before his departure).

Another interesting aspect to the case was the pathologist's finding of popcorn husks in the mouth and stomach of the deceased (also on the bedspread) and a carpet cleaning machine in an adjacent room. During his original interview, the detective had stated that he had cleaned the bedroom carpet earlier in the day (before the shooting). The question that is begged was, did that actually take place after the shooting and was done to cover up signs of a struggle? Perhaps if investigators had looked, they may have found a broken popcorn bowl and popcorn particles in a trash can and popcorn inside the carpet cleaning machine.

Case 2. Homicide or Suicide?

A 911 call came in on a Sunday morning around 7:00 A.M. from a resident in a business/residential neighborhood of possible shots fired. A responding officer found a pickup truck with the driver door partially open and a body lying in a supine position on the ground below in back of a doctor's office in the neighborhood (Figure 16.28).

On initial inspection of the scene, the responding officer observed there were several $20 bills on the ground near the body along with a pager. The body was lying in a pool of blood, and blood appeared to be coming from a wound to the right temple and the

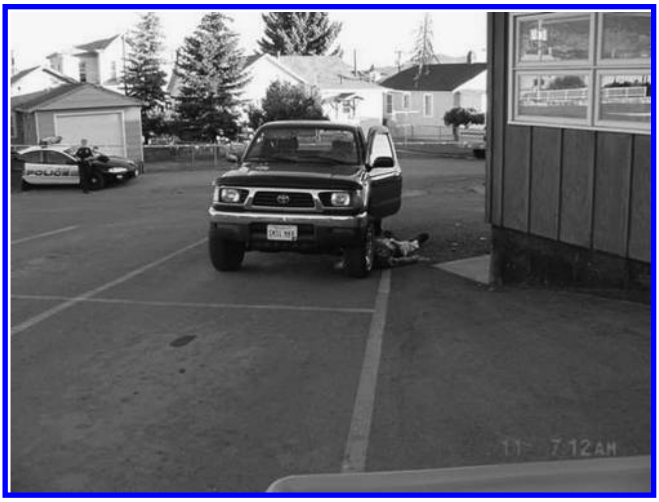

Figure 16.28 Scene of shooting death.

mid-chest of the victim. A revolver was lying in the crotch of the victim. The officer then recognized the victim as an officer in her department who had been off on vacation for the past several days (Figures 16.29 through 16.32).

Immediately, questions are raised by what is observed at the scene:

1. Was this a dope sting operation that went bad, a robbery, or what?
2. Two shots appear to have struck the dead officer, were either or both from the revolver?

As other officers arrive, it is determined that the dead officer was not involved in any sort of clandestine operation but was, in fact, off duty on vacation leave. The revolver serial number was run and came back to the officer. It was noted that the dead officer's wallet, wristwatch, and a ring were all in place. It was also determined that the officer lived a few

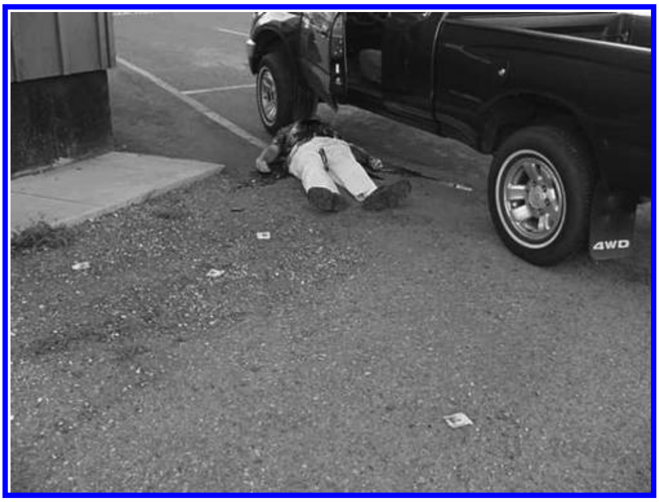

Figure 16.29 Several $20 bills and a pager are on the ground nearby.

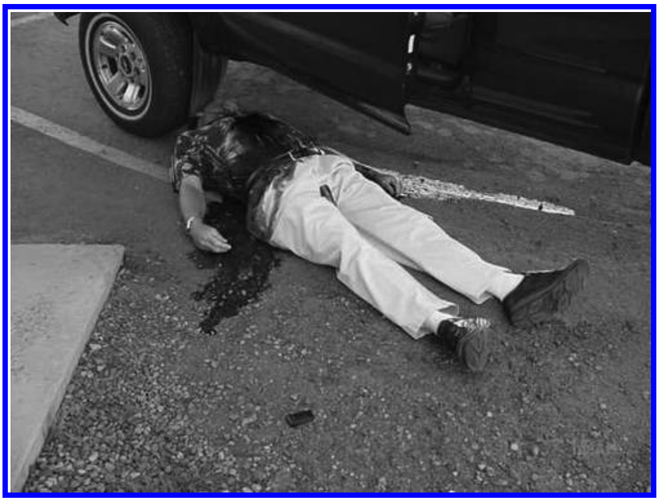

Figure 16.30 A revolver is lying in the victim's crotch.

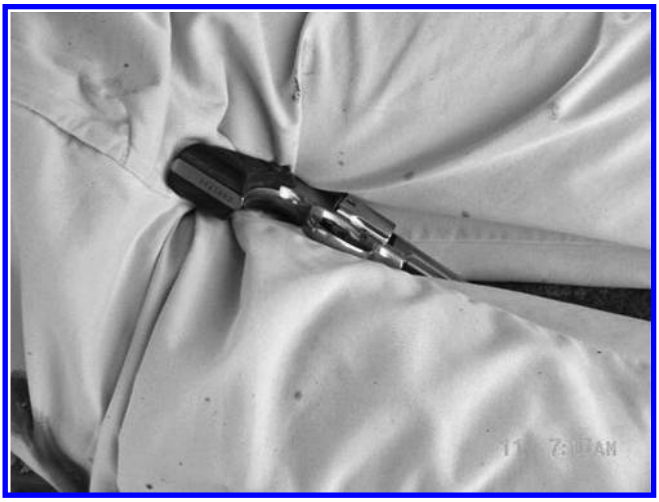

Figure 16.31 The revolver.

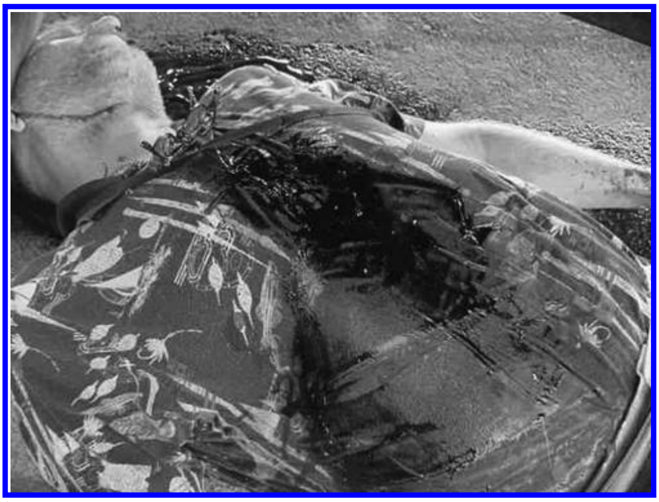

Figure 16.32 Blood from a wound to the right temple (on jaw) and mid-chest.

blocks away. The neighborhood was a low crime area, and it was very unusual for shots to be fired there. There was a ring of keys in the decedent's right hand and, given the fact that the likely fatal wound was to the right temple, it appeared unlikely that the temple shot was self-inflicted (Figure 16.33).

Upon arrival of the death investigator, it was determined that the key ring was actually over a finger, making it possible to have maintained the keys in the right hand and still fire the revolver. However, one of the responding officers pointed out that the decedent was left-handed (suggested by the wearing of his watch on his right wrist). The investigators then observed a fired bullet and a small clump of blood on the ground just beyond the feet of the deceased (Figures 16.34 and 16.35).

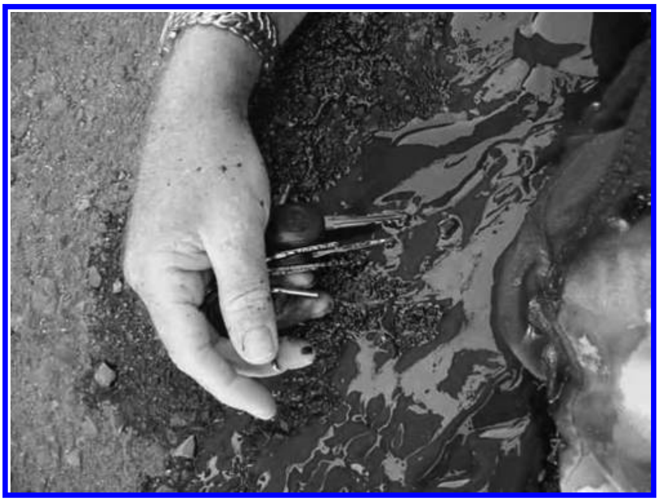

Figure 16.33 Keys in left hand (note the handcuff key and bloodstains on thumb).

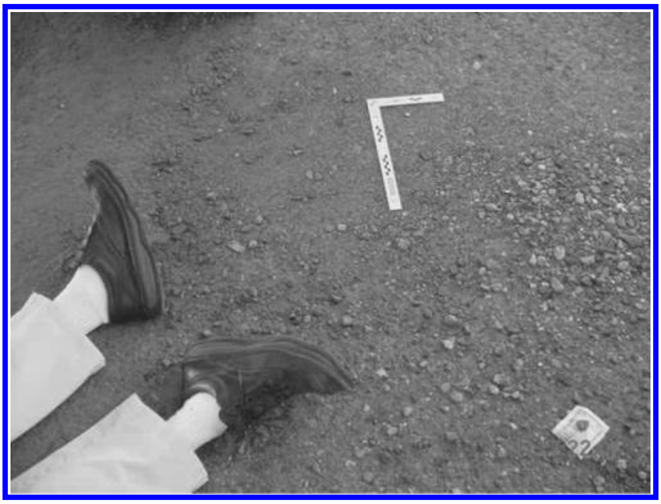

Figure 16.34 Bullet and blood.

A field examination of the revolver revealed its loading status to be four live rounds, one fired cartridge case, and one empty chamber (but out of sequence!). Apparent bloodstains were also visible about the muzzle (Figures 16.36 and 16.37).

Several circular apparent bloodstains were visible on the pants, and of particular interest was a stain on the right sock (Figure 16.38).

The apparent bloodstains on the pants and the sock were later confirmed to be consistent with the decedent, as were the stains on the revolver barrel, the primer of the live round, and the clump from the ground. A search of the parking lot area produced a fired cartridge case similar to those in the revolver and with blood consistent with the decedent's.

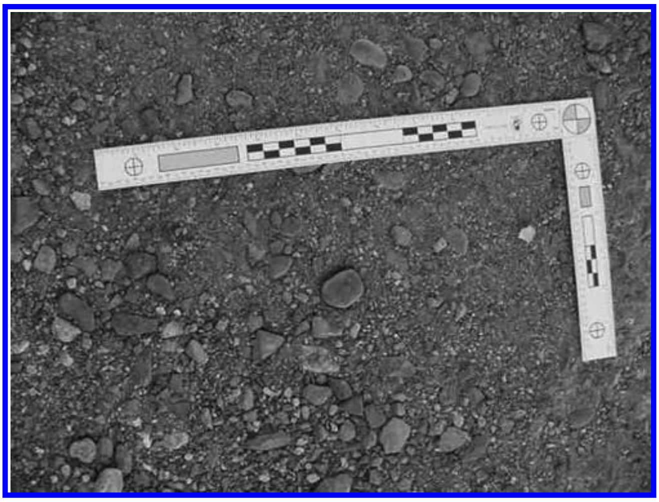

Figure 16.35 Close-up of bullet and clump of blood.

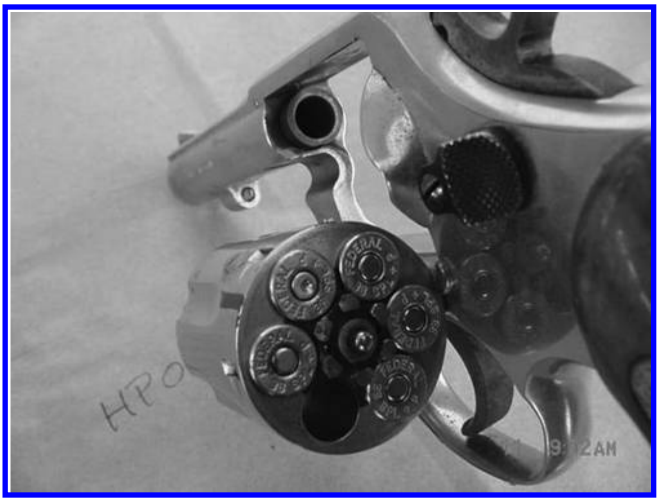

Figure 16.36 **(See color insert.)** Loading status (note the apparent blood on primer of cartridge to the left).

A check with the decedent's family revealed that his wife had recently left him (just before he took his vacation leave). A review of his life insurance policy revealed that in just the past few days he had removed his wife as a beneficiary and had substituted his children.

A canvass of the neighborhood failed to provide any possible suspects or motives. Further investigation failed to turn up anyone who would want to do harm to the decedent. The only motive left was suicide. The only explanation for all the apparently conflicting evidence was the need to mask his suicide to ensure that the children would not be excluded from the life insurance benefits. But how did all this take place?

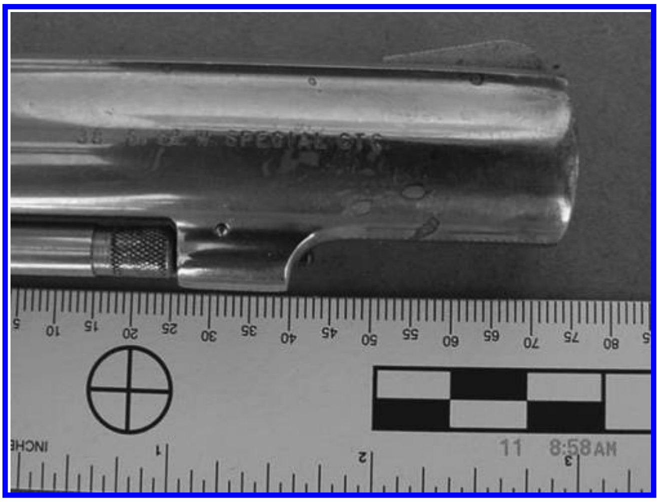

Figure 16.37 Apparent blood on barrel near muzzle.

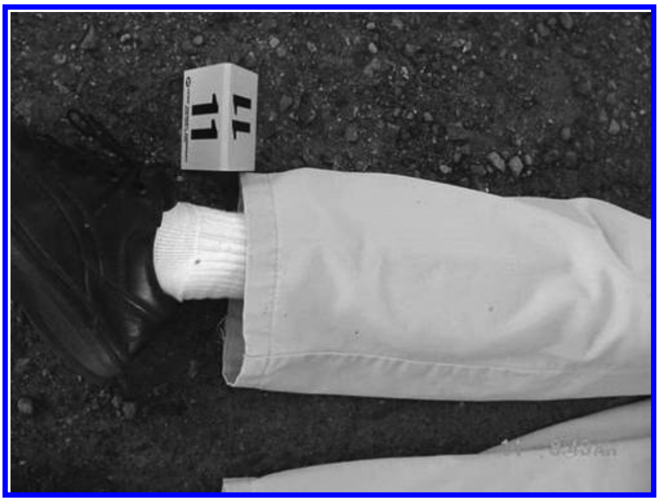

Figure 16.38 Apparent bloodstains on pants and right sock.

Here is a possible sequence of events that could explain all the evidence:

1. He leaves his house early Sunday morning and drives to the rear of the doctor's office nearby.
2. He opens the driver's door and gets out with the revolver.
3. He throws the $20 bills and pager on the ground.
4. He is standing beside his pickup bed facing toward the rear of the truck.
5. He cocks the gun and uses both hand to position and fire the gun into his mid-chest at contact distance getting back spatter on both hands, the bullet exiting his back and falling to the ground behind him along with a clump of blood (forward spatter).

6. He opens the cylinder of the revolver, removes the fired cartridge case, and throws it across the parking lot (where it was later found).
7. He sits down on the ground (legs stretched out in front of him) after taking his key ring and slipping it over the third finger of his right hand and shoots himself in the right temple.
8. Involuntary muscle response results in the gun being carried forward and dropping into his crotch.
9. Expiration of blood from the chest wound produces the circular stains on the pants and right sock.
10. He slumps back with his head against the driver's side front tire where he is found.

Maybe, but here are a few potential problems with that nice, seemingly tidy explanation:

1. The shot to the chest took out his aorta leaving him with about 30 seconds of mobility to do all the rest of the staging according to the medical examiner.
   Possible? By virtue of a reenactment, the answer is yes.
2. Do you believe he came with a preconceived plan to shoot himself twice, realizing that he could shoot himself in the chest and still have the capability of staging the rest of the scenario and then shoot himself in the right temple?
3. Can we say with 100% certainty that no one else was involved, even though there is no evidence of an assailant?
4. Would he have not known that the two bullets would likely be identifiable to the revolver and the revolver would be traced back to him?

These are questions we can probably never answer. There being no suspects generated and there being a likely motive for suicide, the case was closed "by exceptional means."

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Ballistics

17

The term ballistics is frequently improperly used interchangeably with firearm identification. Ballistics is the study of projectile motion, whereas firearm identification deals with the examination and comparison of weapons and ammunition components. Obviously, determining whether a fired bullet or cartridge case was fired from a particular weapon has really nothing to do with projectile motion per se. True ballistics is certainly one aspect of shooting incident reconstruction that must be dealt with from time to time. This is particularly true with long-range shots or other circumstances where bullet trajectories in flight are involved. Questions about bullet behavior on target impact are also ballistics issues as are questions regarding weapon failures such as those resulting from excessive internal pressures.

The study of ballistics is generally approached from three different perspectives: internal ballistics, external ballistics, and terminal ballistics (wound ballistics is a subdiscipline of terminal ballistics). Internal ballistics has to do with bullet behavior and related aspects before the exit of the bullet from the muzzle of the weapon. External ballistics encompasses bullet behavior upon exiting the muzzle and before final target impact. Terminal ballistics deals with bullet behavior upon impact with a target (human or otherwise).

Internal Ballistics

A quick review of some of the basic principles of metallic cartridge case discharge is in order as we begin our discussion of internal ballistics and the behavior of bullets within the confines of the gun barrel. According to traditional firearms and ammunition component design, two things are supposed to happen in order to ensure that a bullet will move down the barrel in the most efficient manner. First, the primer must be detonated by the impact force of the firing pin or striker. The flame created by the detonation of the priming mixture must then enter the confines of the cartridge case and ignite the powder charge. This ignition creates combustion gases that rapidly expand equally in all directions.

As a result of this expansion, the brass cartridge case expands to seal the rear of the chamber. This is extremely important for both the safety of the shooter and the efficiency of the round. No gases should be coming rearward toward the shooter. In the extreme situation, this could result in blowout of the primer or even weapon failure. This chamber sealing case expansion literally takes place in a split second. What is even more remarkable is that it returns to its original shape (more or less) in another split second, as evidenced by the fact that the fired cartridge case can be extracted from the chamber. If this were not the situation, the fired cartridge case would be tightly jammed in the chamber and could not be easily extracted. When one thinks about it, this is a rather remarkable bit of physics in action.

Similar sealing takes place at the muzzle end when the bullet expands to seal the bore. This expansion is known as obturation. Failure to seal the muzzle end of the bore results in blowby of gases. This ultimately erodes the barrel surfaces and makes the weapon inaccurate to say the least. Figure 17.1 illustrates the external characteristics that are visible upon discharge.

Englishman Joshua Shaw, who immigrated to the United States in 1814, is credited for having first designed a metal cup for holding the priming mixture. A piece of metal foil was used to cover the priming mixture. The foil was then shellacked in place, and the assembly was then placed on the nipple of a percussion cap pistol or rifle. With the advent of the self-contained brass cartridge case and its combination with Shaw's primer cup, modern metallic cartridges were born. Figures 17.2 through 17.4 serve to illustrate.

Modern centerfire cartridges are typically made of brass owing to the ability of brass to expand and contract upon discharge as described earlier. The primer cup is held in a primer pocket that is centrally located in the head of the cartridge case, as shown in Figure 17.2.

In addition to the single flash hole design illustrated in Figure 17.3 that was designed by Englishman Colonel Edward Boxer, a double flash hole design was developed by Colonel Hiram Berdan at the Frankfort Arsenal. The North Atlantic Treaty Organization (NATO) 9-mm ball ammunition is typically of the Berdan twin flash hole design, as are many foreign-manufactured centerfire cartridges. Most U.S.-manufactured centerfire ammunition is the Boxer style with a single flash hole.

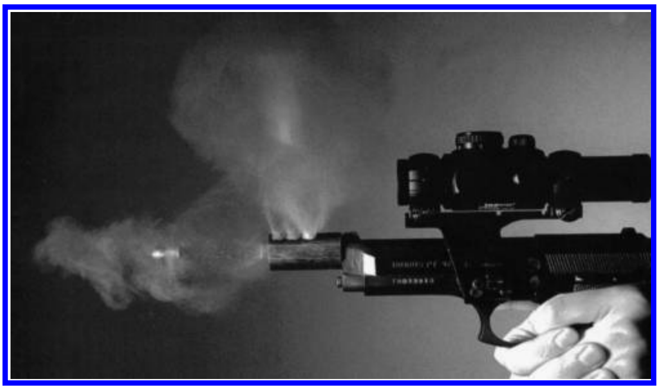


Figure 17.1 Firearm discharge.

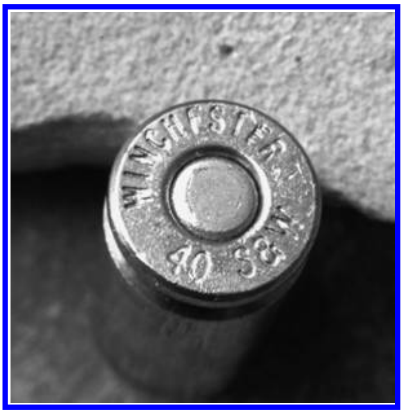


Figure 17.2 Centerfire cartridge with primer in metallic cup.

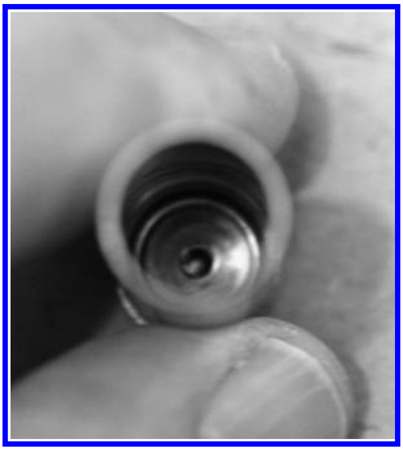


Figure 17.3 Cartridge case opening for primer flame (flash hole).

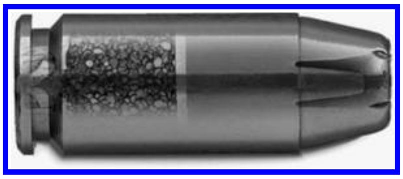


Figure 17.4 Typical modern metallic centerfire cartridge (phantom view).

The only possible implication for this in shooting reconstruction would be the comparison of the cartridge cases found at a shooting scene with those taken from a suspect to demonstrate consistency. Because Berdan-style cartridge cases are less common in the United States, this could add to weight of the circumstantial evidence of similar cartridge case design.

Priming mixtures were originally based on potassium chlorate and then later changed to fulminate of mercury. The problems associated with these mixtures were significant. Potassium chlorate is corrosive to steel. Fulminate of mercury forms an amalgam with brass that, over time, causes it to become brittle and prone to cracking. Most modern primers are based on lead styphnate, although lead-free primers are available from a number of manufacturers.

Once the primer is detonated and the resultant flame passes through the flash hole(s), the gunpowder is ignited. Modern "smokeless" powder consists of either nitrocellulose (single base) or nitrocellulose in combination with nitroglycerin (double base). Originally, "black powder" consisting of a mixture of charcoal, sulfur, and potassium nitrate was used. The disadvantages of this formulation were its corrosive nature and the production of a large quantity of smoke upon combustion. Most modern weapons are designed for smokeless powder, although black powder weapons are still produced and black powder shooting is a popular hobby. The author has had occasion to reconstruct several shootings involving the use of black powder weapons. The common black powder substitute is Pyrodex®, which offers the black powder shooter a noncorrosive alternative. A typical black powder handgun is shown in Figure 17.5.

As mentioned in Chapter 11, modern gunpowder also contains various stabilizers and plasticizers so that the combustion occurs at a predictable and controlled rate. A major consideration as far as rate of combustion is concerned is powder shape or morphology (Figure 17.6). Smokeless powder typically exists in flake (disk), ball, flattened ball, or

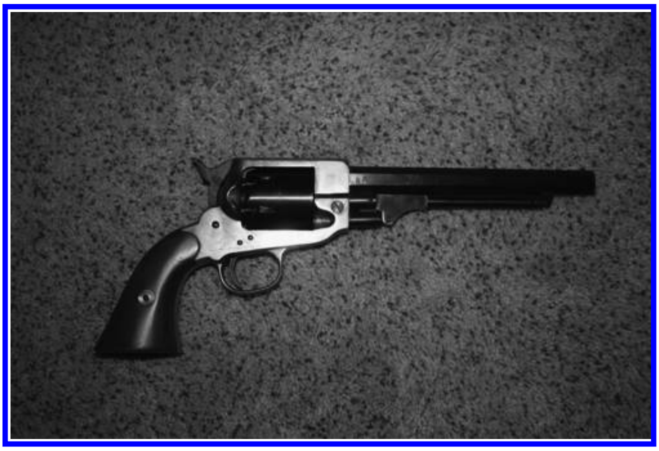


Figure 17.5 Black powder revolver.

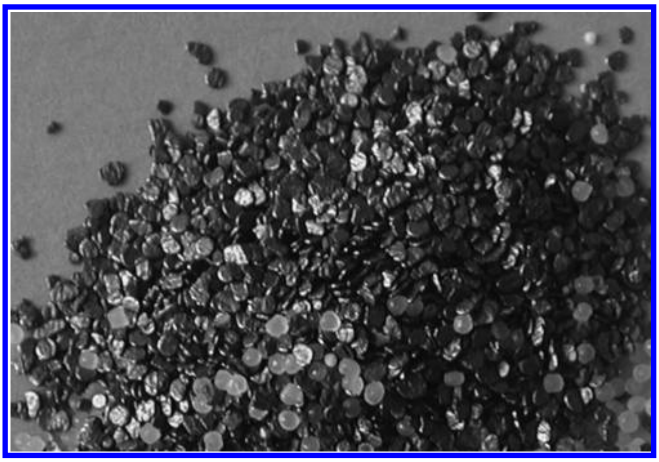


Figure 17.6 Flake-type gun powder particles.

tubular configurations. The rate of combustion increases with an increase in surface area. This is exactly analogous to selecting wood to start a fire in a fireplace. If one wants a rapid, very hot fire, lots of small pieces (kindling) are used as opposed to intact logs. The considerations regarding gun powder can be summarized as follows.

Gun Powder Considerations

- Morphology (flake/disk, ball, flattened ball, tubular)
- Coatings (control burning rate)
- Single base (nitrocellulose) or double base (nitrocellulose + nitroglycerin)
- Smokeless versus black powder

With regard to the variables associated with the study of internal ballistics in addition to the primer and the powder charge, we must also consider the chamber capacity of the weapon, the barrel length, the caliber, and the bullet design and dimensions. The powder chamber capacity is defined as the number of grains of water that the cartridge case can hold. This is a standard capacity measurement as used in ballistics determinations.

The bullet design considerations include the bullet diameter (caliber), the overall length, and the weight. Obviously, things such as length and weight figure into the friction that the bullet will display inside the confines of the gun barrel. Barrel length will also be a big consideration. In general, the variables that affect internal ballistics are summarized in the following list.

- Variables affecting internal ballistics
  - Chamber capacity
  - Amount of powder
  - Burning rate of powder
  - Diameter, length, and weight of bullet
  - Barrel length and caliber
  - Primer (uniformity of ignition)

With regard to internal ballistics, there are nine events that comprise the scope of the discipline. These events are as follows:

- Firing a cartridge (the scope of internal ballistics)
  - Trigger is pulled.
  - Hammer (or striker) strikes primer.
  - Priming mixture explodes (flame passing through flash hole).
  - Powder is ignited.
  - Gases are produced and expand equally in all directions.
  - Bullet/shot pellets start down barrel/Cartridge case expands to seal breech.
  - Bullet obturates (expands) to seal bore.
  - Gas pressure builds to a peak, then decreases.
  - Bullet exits barrel.

A couple of notes regarding weapon functioning are in order here. If the cartridge case is not square with the breech face, the pressures created upon combustion can cause torque that, simply put, prevents the bullet from entering the bore in proper alignment (i.e., axis of bullet = axis of bore). This can produce a significant deviation in the impact point. With revolvers, this effect is manifested by "shaving" of the bullet as it moves from the misaligned chamber into the barrel. This can produce fragments that can result in injuries to individuals within close proximity.

Ideally, the buildup of pressure within the bore maximizes just before the exit of the bullet. Different barrel lengths would, theoretically, benefit from different burn rates. Commercial ammunition must take into account all possible common barrel lengths. Thus, more than adequate powder is present for short barrels. The good news for shooting reconstruction is that this ensures that partially burned and unburned powder particles will emanate from the muzzle and allow the potential for muzzle-to-target distance determination. A typical pressure curve is shown in Figure 17.7, where the pressure (in pounds per square inch) is shown versus time (in milliseconds). The volume of gas produced is huge compared to the volume of the unburned powder (about 4700 times as great).

As an example of the amount of pressure generated inside the bore, the modern .308/5.56/.223 caliber rifles attain pressures of more than 50,000 psi within milliseconds of discharge.

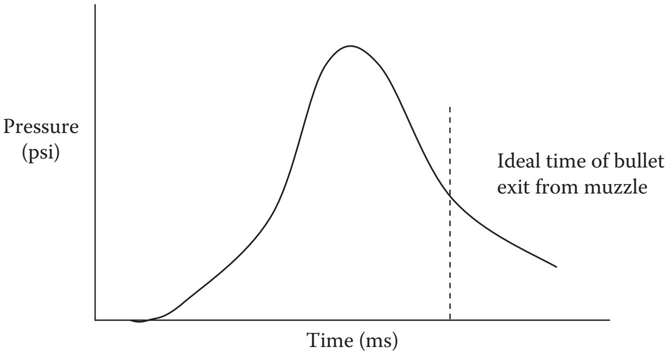


Figure 17.7 Internal pressure curve.

The longer the barrel, the more pressure that gets exerted against the bullet, and hence, the higher the velocity of the bullet. Velocity may be altered by changing the burning characteristics of the powder or by using more powder (requires a longer case). An example would be a .45 GAP cartridge compared to a .45 ACP cartridge (Figure 17.8).

Maximum velocity is reached just past the peak pressure point. The corresponding barrel lengths associated with various commercial loads for this to occur vary as would be expected. For example, in a .22 long rifle, peak pressure is attained in about 16 inches. If the barrel exceeds 16 inches, friction between the bore and the bullet actually retards the round. For a .308 round using commercially available ammunition, a barrel length of 30 to 36 inches is required to obtain complete combustion and peak pressure. This barrel length is generally too long for tactical use; therefore, some loss in performance is accepted in order to gain practical efficiency for law enforcement.

In theory, the shorter the barrel (or the lighter the bullet), the faster the required burn rate to ensure maximum barrel pressure just before bullet departure. Obviously, as the pressure rises, the bullet will be imparted with greater velocity. Given these basic principles of internal ballistics, it is pretty obvious that weapons such as a snub nose .44 Magnum fail

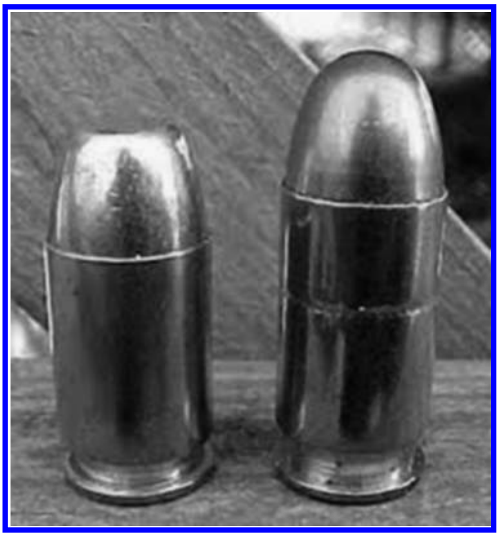


Figure 17.8 GAP (left) compared to 45 ACP (right).

to capitalize on the inherent energy in the large powder charge present because of the short barrel and low expansion ratio.

When a bullet exits the mouth of a cartridge case and contacts the rifling, the effect can be likened to striking the chamber end of the barrel with a hammer. According to Newton's third law, an equal force will be generated at the butt of the handgun or long gun. This force is manifested as longitudinal vibrations within the barrel.

Spin stabilization of the bullet within the confines of the barrel is what allows the bullet to maintain a trajectory upon exiting the muzzle. The twist direction may be right (clockwise) or left (counterclockwise) depending on the barrel rifling characteristics. Most barrels, however, are right-hand twist. Also, the rate of twist of the barrel will determine how fast the bullet is rotating upon muzzle exit. Barrel rate of twist is given designations such as "1 in 12" or "1 in 6." This means the bullet completes one rotation about its long axis for every 12 or 6 inches, respectively, of barrel length. These concepts are illustrated in Figures 17.9 through 17.11.

If one looks at the 4-inch barrel cut-away in Figure 17.11, it is obvious that the bullet will not make a complete revolution (360°) before exiting. That is quite alright and, in fact, is typical of handgun barrels.

As a rule, the longer and heavier a bullet is in any given caliber, the faster the twist needed to stabilize it. A typical round will have 150,000 to 200,000 revolutions per minute. If a bullet base is not square with the plane of the muzzle upon exit, an "axial error" will

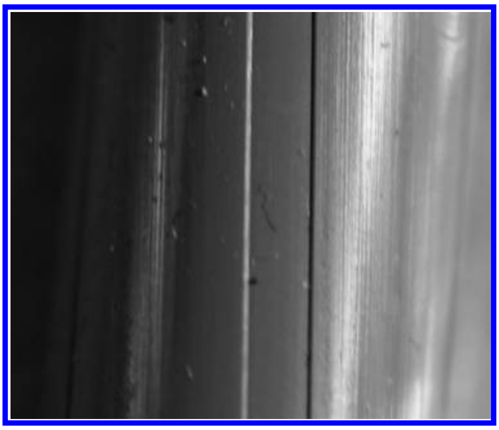


Figure 17.9 Cast of barrel with left twist rifling.

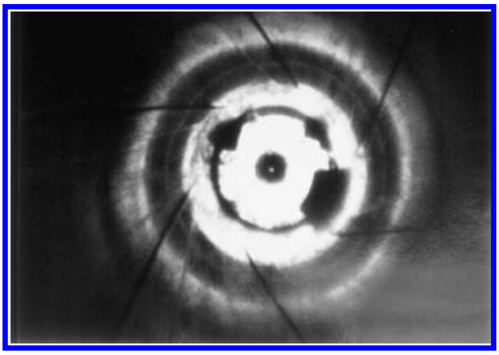


Figure 17.10 View down bore of AK-47 with right twist rifling.

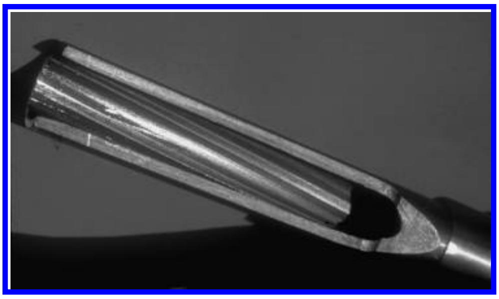


Figure 17.11 Cutaway of handgun barrel showing left twist rifling.

cause the bullet to go off target. This is overcome, to a large degree, by a boat tail design (see Figure 17.12). The boat tail design is considered to be superior to other base designs. The boat tail decreases the turbulence at the base during flight.

The firing pin spring pushes forward with a force of approximately 25 foot-pounds on the average. Once again, Newton's third law dictates that a comparable force be applied rearward. Similarly, the propelled bullet exerts an equal force forward and rearward. The net effect is, of course, recoil. The point of all this is that the recoil effect is the same as the bullet impact effect. The recoil effect is diminished by the greater mass of the weapon as compared to the bullet. In terms of the significance in shooting reconstruction, bullets do not knock people down, spin them around, or stop them in their tracks as they run forward, even though Hollywood would have us believe otherwise. On the other hand, people do react to being shot in a variety of ways. As someone once pointed out, if you stick someone with a pin, they may jump into the air, yell out, etc., but it is simply their reaction to the pin not the mass of the pin, or the lack thereof.

One of the ill-conceived arguments for a shot from "the grassy knoll" in Dallas when President Kennedy was shot was that his head could be seen "snapping back from the bullet that struck from the front" in the 8-mm film taken by Abraham Zapruder. On close examination of the digitized version of the film, run in slow motion, the viewer can clearly detect a brief lapse between the obvious bullet impact from the rear and the movement of the head backwards. The movement was likely an autonomic nervous response that followed the bullet impact to the back of the head.

This business about bullets and shot pellets causing various movements of human bodies comes up rather frequently in shooting incidents. The investigator should understand

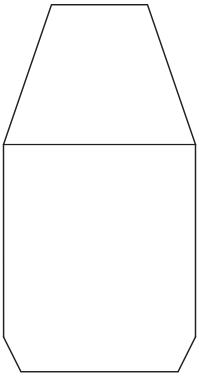


Figure 17.12 Boat tail bullet.

the physics involved in order to be able to explain to the jury and others why the portrayals in the movies and on television are wrong. This explanation must be tempered, however, with the fact that people may definitely react in various ways to being shot.

A rather dramatic, although unorthodox and dangerous, illustration of these principles was provided in a video titled "Deadly Weapons" produced by Anite Productions in California a number of years ago. In one segment attesting to the proficiency of a particular brand of "bullet proof" vests, the designer of the vests shoots another individual at point blank range in the chest with a .308. The individual taking the round was, of course, wearing one of the touted vests. The impact of the .308 military ball round fails to move the recipient off of his one-leg-in-the-air stance: one picture can be worth a thousand words!

A frequent issue in shooting reconstruction is the use of weapons (rifles and shotguns usually) having sawed-off barrels. The net effect on velocity depends on how much of the barrel was removed as well as the size of the cartridge case in relation to the barrel diameter (caliber or gauge). This involves what is termed expansion ratio. Expansion ratio is the ratio of the capacity of the powder chamber to the capacity of the chamber plus the bore. Weapons with high expansion ratios (small cases in relation to bore diameter) tend to lose less velocity than do weapons with low expansion ratios (large cases in relation to bore diameters). The best way to obtain a quantitative answer as to the effect of sawing off a barrel is to do chronographic studies using the weapon and ammunition involved.

External Ballistics

External ballistics has been recognized and explored for thousands of years. The word "ballistics" can be traced to ancient Greece. The Greeks used the word in reference to ancient throwing machines in approximately 300 B.C. Some of the best-known scientists of history delved into the study of projectiles in motion and helped develop it as a true science. These scientists include Leonardo da Vinci, Galileo, Sir Isaac Newton, Francis Bacon, and Leonhard Euler.

Galileo was a ballistics consultant to the arsenal in Venice and used his famous dropping cannonball experiments of the Leaning Tower of Pisa to prove that bullet trajectories are parabolic. Galileo, although brilliant in his own right, failed to consider the significant effect that air friction has on all bodies in motion. This—coupled with his inability to determine muzzle velocities—prevented him from being able to calculate accurate trajectories.

Benjamin Robins' invention of the ballistic pendulum in 1740 allowed reasonably accurate muzzle velocity determinations. This, along with Newton's invention of the calculus and his understanding of gravitational effects, allowed trajectories to be calculated. Robins came to the then amazing conclusion that the effects of air friction (drag) were considerably greater than gravitational effects on projectiles put into motion. Air friction or drag *slows* the bullet down, whereas gravity *pulls* (i.e., accelerates it) the bullet to earth. Gravity produces a constant acceleration on a body in motion at the rate of 32 feet per second. This acceleration continues until impact with the target (or ground) occurs. The idea, of course, is to hit the target, not let the bullet go to ground. The effect of gravitational acceleration over time can be illustrated as follows:

After 1 second, velocity = 32 feet per second
After 2 seconds, velocity = 64 feet per second

After 3 seconds, velocity = 96 feet per second
After 4 seconds, velocity = 128 feet per second

And so on.

There are a number of terms used by ballisticians when discussing external ballistics that the shooting reconstructionist should be familiar with.

External Ballistics Terminology

- Back curve—portion of trajectory below the critical (kill) zone beyond the point blank range
- Ballistic coefficient—a measure of a bullet's ability to resist air friction and maintain velocity and energy in flight (signified by a number)
- Bore centerline—visual line of center of the bore
- Bullet trajectory—parabolic path of flight of bullet
- Critical zone—known as the "kill zone," a 6- to 8-inch diameter area for big game/man
- Initial point—range at which bullet trajectory first crosses line of sight (approximately 25 yards down range)
- Line of sight—visual line from sight to target
- Maximum ordinate—maximum height of bullet trajectory above the line of sight (usually slightly beyond the midrange point of the trajectory)
- Maximum pointblank range—maximum distance at which the bullet remains in the critical zone (no more than an 8-inch drop for a man-sized target)
- Mid-range trajectory—bullet height halfway to the zero range
- Minute of angle (MOA)—1/60th of a degree; equates to approximately 1 inch of pattern spread (group) at 100 yards
- Yaw—angle between the longitudinal axis of a projectile and the line of the projectile's trajectory
- Yawing—rotation of a nonstabilized/destabilized bullet about its longitudinal axis. Produces tumbling as its most severe consequence
- Zero range—maximum range at which line of sight and trajectory intersect

Most of these concepts are represented by the bullet trajectory diagram in Figure 17.13.

Before spin stabilization or as a result of impact with an intermediary target, a bullet has inherent destabilization characteristics in flight (yawing, precession, and nutation) (Figure 17.14). With time and distance, this can become so pronounced as to produce tumbling. This can be recognized by the characteristic "keyhole" entry hole. These same effects also take place within the human body (see next section).

If the barrel of a gun is held parallel to the ground and fired, the effect is a parabolic trajectory to earth as shown in Figure 17.15.

If we eliminate drag and consider only the effects of gravity, a bullet fired parallel to the ground and one simultaneously dropped from the same height above ground would strike the ground at the same time, the fired bullet would just be farther away. This is simply because gravity would be acting equally on both bullets.

As an example of the comparative effects of drag and gravity on a bullet in flight, consider the following example. If we could eliminate the effect of gravity, a .30 caliber

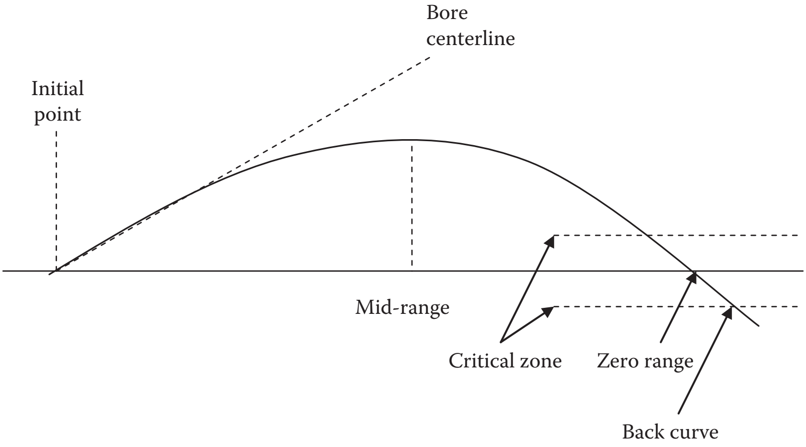

Bore
centerline
Initial
point
Mid-range
Critical zone
Zero range
Back curve

Figure 17.13 Trajectory diagram.

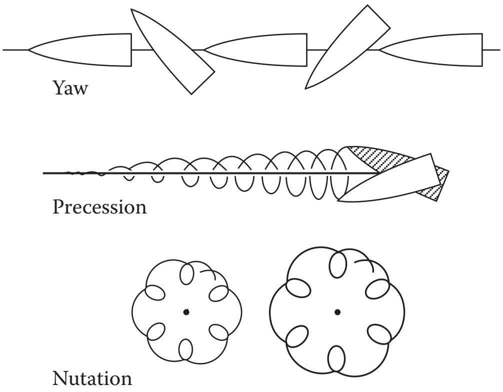

Yaw
Precession
Nutation

Figure 17.14 Inherent destabilization forces for projectiles in motion.

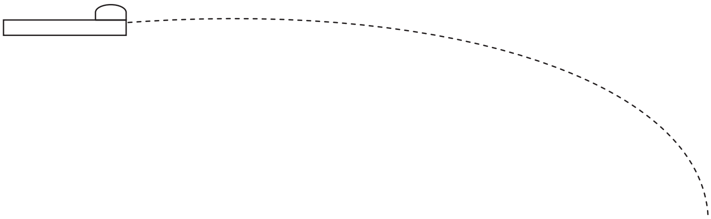


Figure 17.15 Effect of gravity on trajectory.

165-grain bullet fired parallel to the ground would travel just under 2 miles. The same bullet fired in a vacuum (no drag effect) would travel 43 miles and strike the ground at the same velocity it left the muzzle with!

The concept of a "standard bullet" to allow comparison of various bullet designs (shapes) was introduced in the mid-nineteenth century. With this concept came the term ballistic coefficient as a measure of "bullet efficiency." Bullet trajectory for the standard bullet could be calculated and used to determine the proposed trajectories for other types and styles of bullets.

In 1965, Winchester published several bullet drag tables based on four standard drag models for four families of bullets. These models cover the majority of sporting bullets. Additional models have been derived for other bullets. These models are denoted by the letter G along with a number or letter. The G1 model is a widely used drag model in the firearms industry. The reader is invited to do more in-depth reading on the subject in any of a number of fine ballistics texts that have been published over the years. Thanks to modern computers and ballistics software, the calculation of bullet trajectories is quick and easy. Galileo and Newton would no doubt be duly impressed!

Figures 17.16 through 17.20 were prepared by the author using Oehler Ballistics software (Ballistic Explorer-Oehler Research, Inc., Austin, TX, USA). These represent the type of information that ballistics software is capable of providing for shooting reconstructions. This comes into play whenever shots are fired beyond the close ranges of a few feet or yards typically encountered and become increasingly significant as the muzzle-to-target distance increases.

As discussed in Chapter 7, there is a free app for ballistics available online from Winchester Corporation. The app, however, is limited to Winchester ammunition only. Other commercially available forensic ballistics software can be purchased through various sources such as Midwayusa.com (Sierra Infinity Exterior Ballistics Software Version 7).

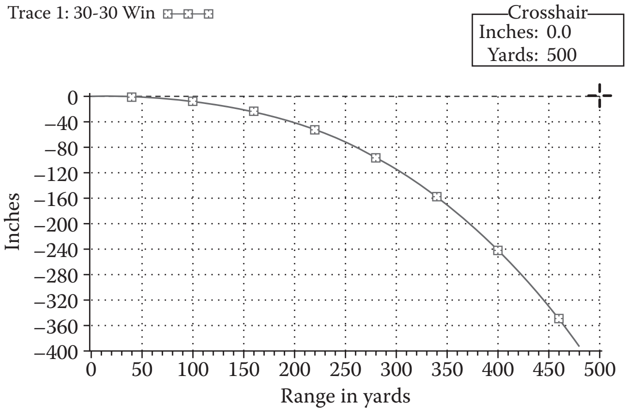


Figure 17.16 Bullet drop.

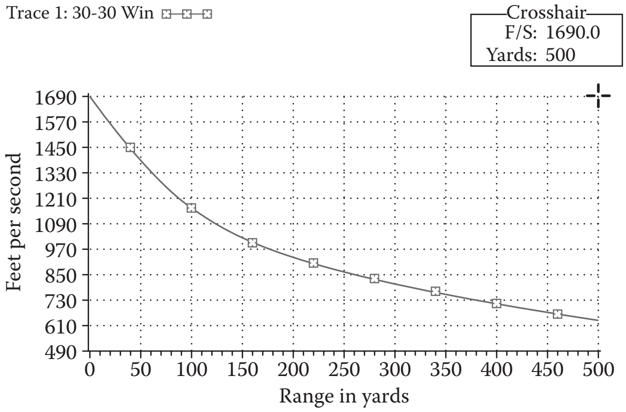


Figure 17.17 Bullet velocity.

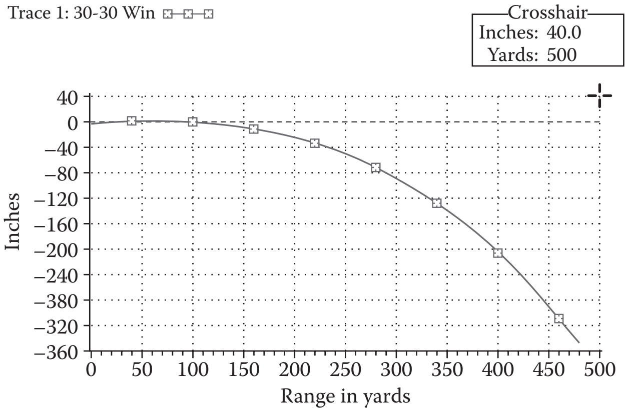


Figure 17.18 Bullet path.

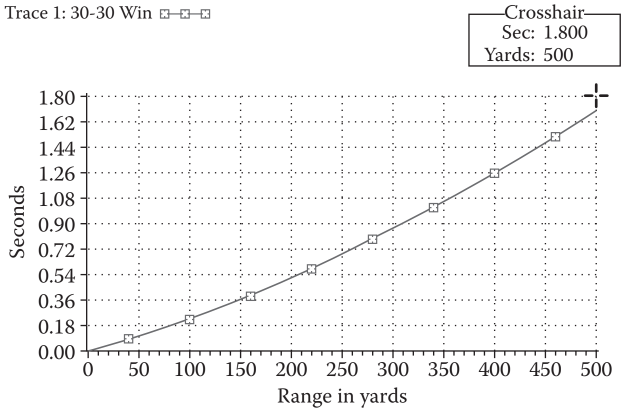


Figure 17.19 Time of flight.

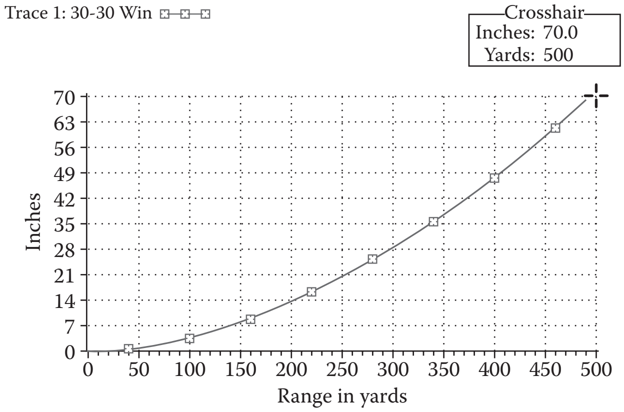


Figure 17.20 Wind drift.

For shooting reconstructions involving close-range shots (under 100 yards), external ballistics considerations are pretty much the subject of academic discussions rather than having any major implications. The effect of a change in ballistic coefficient is relatively small, even at greater ranges. For example, a flat base bullet may be compared to its boat tail cousin with little noticeable differences as seen in the following comparison: two 165-grain hollow point bullets (one flat base and the other boat tail) with 2700 feet per second muzzle velocity and 225-yard zero range are compared as to bullet path at 300 yards. The flat base bullet is found to have a drop of 6.8 inches, whereas the boat tail bullet shows a 6.6-inch drop. This is basically insignificant, given the percent error that is associated with such measurements.

Environmental effects can be somewhat more pronounced. Ballistics tables are generally based on "standard conditions"—meaning 0.0 altitude, 59°F, 29.53 inches of mercury, and 78% relative humidity. Looking first at altitude effects, in general the higher the altitude at which the shot takes place, the higher the bullet will strike. This is why hunters resight their rifles when going into mountainous regions to hunt when they originally sighted in their weapons at low altitude. As a rule, the bullet strike point will only change a fraction of an inch for each 1000-foot change in altitude.

Shots fired uphill or downhill will strike high. This is because gravity acts on the bullet only on its horizontal component. This is illustrated in Figure 17.21.

As the bullet leaves the barrel, the movement of air (wind) can alter the strike point with respect to the point of aim. A wind blowing at a right angle to the line of departure (crosswind) will have the greatest effect. Tailwinds and headwinds only produce significant vertical deflection for shots over approximately 600 yards. As an example of wind effect, a .308 Sierra 168 grain boat tail hollow point with a 10-miles per hour right angle wind will be deflected more than 3 inches at 200 yards. At 400 yards, the deflection will be more than 13 inches. At 1000 yards, a 1-miles per hour crosswind can deflect the same bullet more than 7 inches.

Temperature will affect both the muzzle velocity of a bullet and its trajectory. The ambient temperature will be a factor for ammunition in storage. The gun barrel will also

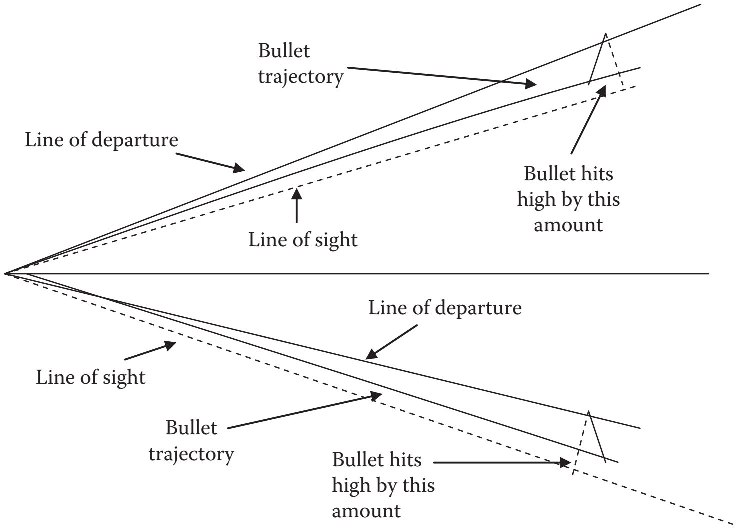


Figure 17.21 Uphill–downhill trajectories.

be affected by temperature changes. A cold barrel will result in a smaller internal diameter and a resultant increase in friction as compared to a hot barrel. As a rule, the hotter the temperature, the higher the shot will impact the target. For each 15° increase in temperature, a corresponding fractional increase in bullet rise will be produced.

If shots are fired in the rain, the resultant increase in humidity and air density causes the bullet to impact its intended target lower than otherwise. The changes are generally quite minimal, however, and only a consideration for long-range shots of the order of 1000 yards or so. A similar result is produced for shots fired when it is snowing.

All these issues are actually nonissues in the context of most shooting incidents because close-range shots are generally involved. Even in the instance of police sniper shootings, shots of less than 100 yards are the average. Accordingly, if a rifle is zeroed in for 200 yards, the potential environmental considerations on bullet impact are negligible. For those occasional shootings involving long distance shots, appropriate consideration must be given to these effects.

Terminal Ballistics

Terminal ballistics has to do with bullet behavior upon impact. For shooting reconstruction, it is important to have an understanding of terminal ballistics for inanimate targets as well as human targets. In the case of human targets, wound ballistics is what we are concerned with. Once again, there are some terms that the reader should become familiar with.

Terminal Ballistics Terminology

- Armor piercing—bullet constructed of hardened steel or with a steel core
- Fragmentation—disruption of a bullet into smaller fragments
- Full metal jacket—nose of the bullet is fully encased by the jacket (open base)
- Full metal case—both the base and the nose of the bullet are fully encased by the jacket. Typical military bullet construction where expansion is not desired
- Hollow point—a cavity in the nose of the bullet designed to produce expansion (typical hunting bullet)
- Minimum perforation velocity—the minimum velocity required for a projectile to perforate human skin largely depends on projectile shape and mass, but ranges from about 200 to about 300 feet per second
- Permanent cavity—cavity in the tissue due to the passage of a bullet (does not contract after bullet passage)
- Temporary cavity—cavity resulting from temporary tissue displacement following bullet passage (collapses after the bullet passes through)
- Penetration depth—final depth to which a bullet penetrates

The reader should note that several commonly used terms do not appear in this short list. Most notably, perhaps, is the absence of the terms “killing power,” “stopping power,” and “knockdown power.” The reason for this is that these are erroneous terms that have no place in a legitimate discussion of terminal (wound) ballistics. The reader should recognize the fallacy of these terms after reading the following discussions.

In general, tissue damage is proportional to the size of the bullet and the energy transferred. Thus, the old saying concerning the outcome of a gunfight ("Whoever has the gun with the biggest hole in the end wins") seems appropriate. Tissue damage is a permanent effect and, thus, is an important consideration in terms of lethality. However, even the most disruptive heart wound cannot be relied on to prevent aggression before 10–15 seconds or more have elapsed.

In terms of immediate incapacitation, the "principle of the two Ps" is all-important—that is, bullet placement and bullet penetration. In order for there to be immediate incapacitation, the bullet must impact the appropriate area of the body (the first "P"—placement). Once the bullet strikes the target in the right location, the bullet must be able to penetrate the tissue to an appropriate depth (the second "P"—penetration). The two areas of the body wherein bullet impact produces instant incapacitation are the spinal cord and the brain stem. Thus, the shooter must be capable of placing a shot to the brain stem or spinal cord areas of the body, and the bullet must be capable of passing through intermediary tissue and bone and reaching these vital regions.

Massive disruption of the heart and/or major blood vessels of the torso will cause circulatory collapse and, ultimately, death but no immediate incapacitation. An aggressor can do a lot of damage in 5–10 seconds. This is why the Federal Bureau of Investigation (FBI) abandoned the 9 mm in favor of the .40 caliber following the well-known bank robbery shootout in Miami years ago. In that incident, FBI agents were firing their 9-mm handguns and hitting the aggressors but they kept coming, fueled by sheer determination rather than alcohol or other drugs. A number of agents lost their lives in that incident and lack of proper firepower was cited as a contributing cause.

When a bullet strikes and passes through human tissue, crushing of the tissue and stretching of the tissue result. Tissue crushing produces what is commonly referred to as the "permanent cavity." The outward, centrifugal stretching that takes place is responsible for the temporary cavity. A temporary cavity is just that; it does not persist, but collapses back to its original configuration. Accordingly, it is the permanent cavity that produces the lethal effect of a gunshot. A representation of the permanent and temporary cavities is presented in Figures 17.22–17.24. Note that the bullet tumbles in the second example (Figure 17.23), producing a more pronounced permanent cavity and resulting in the bullet winding up base first (180° change in orientation). This tumbling is the result of yawing that begins upon impact and becomes so severe that the bullet will ultimately reverse itself if there is

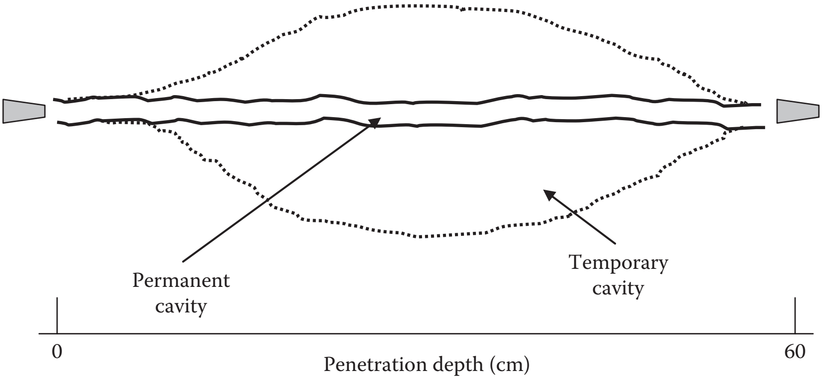


Figure 17.22 Temporary and permanent cavities.

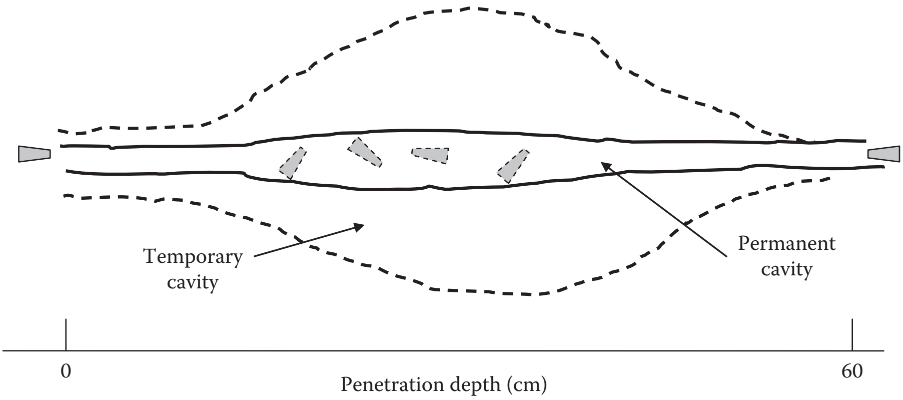


Figure 17.23 Temporary and permanent cavities (tumbling).

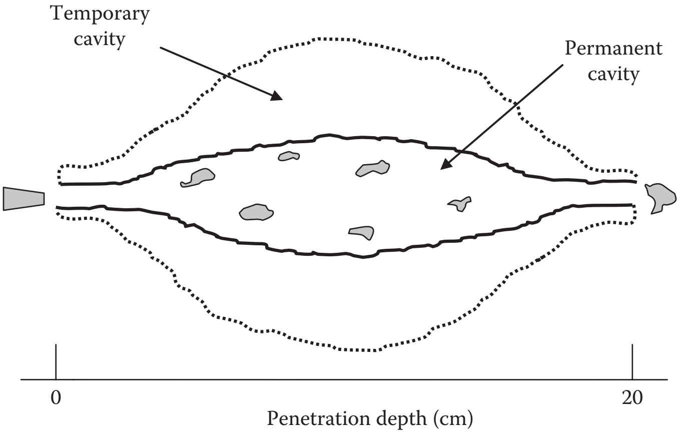


Figure 17.24 Temporary and permanent cavity with fragmentation.

sufficient tissue depth. Military .308 NATO bullets and the stubby 7.62 × 39 bullets are well known for this, whereas the M-16 round (.223 caliber) is known for its propensity to fragment within the body (Figure 17.24). Note the relative differences in penetration depth for these different bullet behaviors.

A case that the author was involved in serves as an example of what the investigator might see as a result of yawing upon impact with tissue. The author was investigating a shooting that took place in a South American country in which the driver of a vehicle was shot to death as he sat in his vehicle parked at the curb. The shots were fired from the front passenger compartment as evidenced by fired cartridge locations and the general trajectories of the shots. One bullet perforated the man's neck. A bullet was found in the "B" pillar on the interior side in line with the neck wound. The bullet was lodged in the pillar *base first*. Clearly, the bullet had reversed itself as it passed through the victim's neck. The bullets fired into the victim were full metal case 9 mm. The expansion of the base is evident in the image of the recovered bullet (Figure 17.25).

Studies of bullet behavior in human tissue are simulated using gelatin blocks. These 25 × 25 × 50-cm blocks of 10% gelatin have been calibrated to reproduce the crush and stretch seen in living tissue. The result of test firings into gelatin blocks are transposed onto

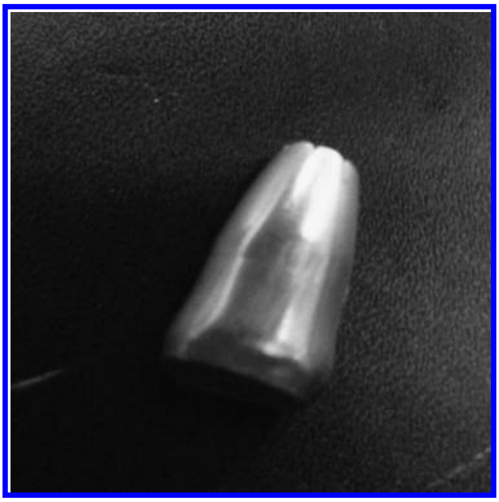


Figure 17.25 Bullet recovered from vehicle (note expansion at base).

a scale drawing called the wound profile (Figures 17.22 through 17.24). By studying and comparing these wound profiles, it is possible for a wound ballistics expert (pathologist) to get a pretty good idea of what sort of tissue disruption to expect in a particular anatomical location. Also, the gelatin block studies allow a determination to be made as to the depth of penetration for the bullet/load under study.

There are a number of misconceptions regarding wound ballistics that need to be explored. These misconceptions are generally based on half-truths and need to be fully understood in order to appreciate their limitations.

Common Misconceptions Regarding Wound Ballistics

- *High velocity bullets are more devastating than low velocity bullets*—High velocity rounds tend to be lighter and more prone to fragmentation. Fragmentation does result in significant tissue disruption. Low velocity rounds, on the other hand, tend to be larger/heavier resulting in deeper penetration and greater tissue destruction (larger permanent cavity).
- *The larger the temporary cavity, the more devastating the resultant wound*—Kinetic energy transfer has no wounding effect in and of itself. It is the transfer of kinetic energy that is responsible for the production of the temporary cavity. Temporary cavity tissue displacement can disrupt blood vessels and even break bones in rare instances, but elastic tissues such as the bowel wall, muscle, and the lungs are pretty resistant to damage. Solid organs such as the liver, however, are not. The loss of kinetic energy results in the bullet stopping, a preferred occurrence as opposed to exiting the body particularly in officer-involved shootings (i.e., avoiding exiting and striking "friendlies").
- *A bullet needs to expand as much as possible and as soon as possible to be effective*—The key here is not expansion per se, but penetration. Although expansion is desirable, the depth of penetration is all important in terms of immediate incapacitation. Any bullet that will not reliably penetrate 10 to 12 inches of soft tissue is inadequate.

- *Bullets passing through only soft tissue maintain their trajectories*—Gelatin studies and case evaluations clearly show that yawing takes place upon impact with tissue and tumbling often results both within the body and upon exiting. Thus, bullets do not have to impact bone in order for destabilization to occur. When bullets do strike bone, destabilization/fragmentation is likely, as shown in Figures 17.26 and 17.27.

It is clear that there are a lot of variables associated with wound ballistics, and one should consider the specifics of the case at hand rather than relying on broad generalities concerning the topic. The individual charged with reconstructing a shooting should seek out the assistance of a qualified forensic pathologist in evaluating issues pertaining to wound ballistics, particularly in predicting whether an individual had mobility after bullet impact and for how long. At the least, a review of the autopsy report to determine if injuries to the spinal cord or brain stem were produced is a must for the shooting reconstruction expert.

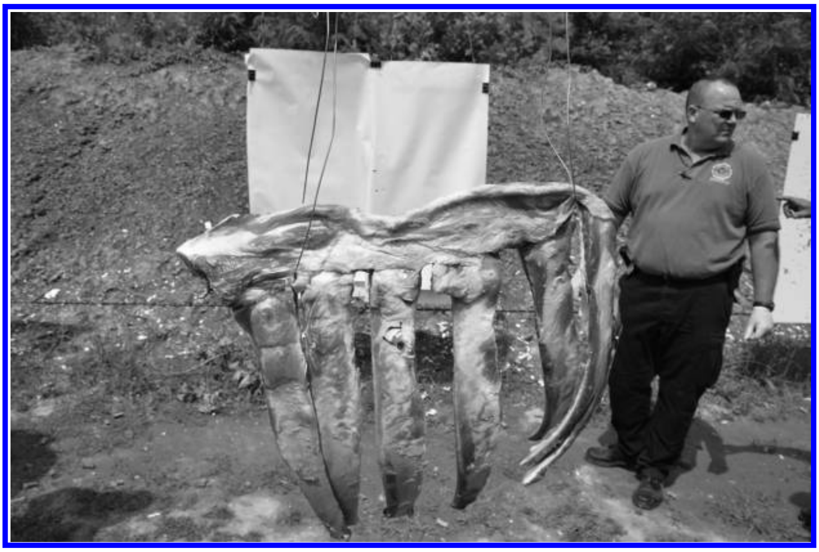


Figure 17.26 Bullet deflection study using bovine ribs (witness panel is 6 feet behind).

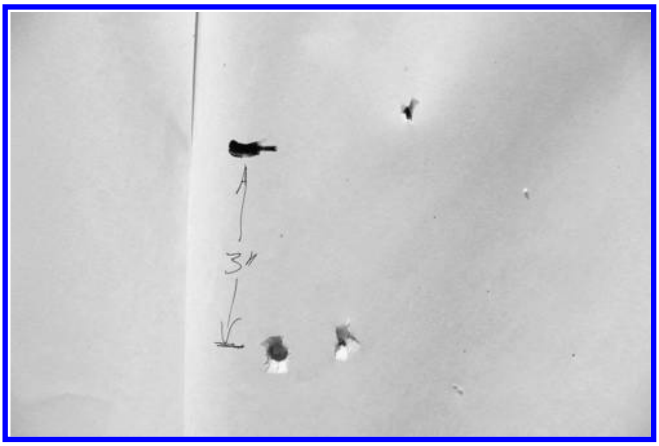


Figure 17.27 Witness panel showing deflection and fragmentation.

Another common misconception is that bullets designed to expand must not have impacted their intended target if expansion did not take place. The best-known example of this, of course, is the so-called pristine bullet in the assassination of President Kennedy. In that instance the bullet first passed through President Kennedy's neck, entering from the rear, before passing through Governor Connolly's shoulder and wrist and entering his thigh. A subsequent study of this shot concluded that the bullet was tumbling as it entered Governor Connolly because of yawing that began inside the President's neck. Much ado has been made about the lack of expansion or "significant" damage to that bullet over the years. The fact of the matter is that there was visible damage to the nose of the bullet, although there was no expansion. However, such "pristine" bullets are found in shooting incidents from time to time. Hollow point bullets sometimes impact relatively soft materials, such as sheet rock, that fill the nose cavity and prevent expansion. The same thing can result from impact with human tissue. Thus, the presence of a bullet that has not expanded should not necessarily be taken as evidence that it did not pass through someone or something.

In a case the author investigated, a 9-mm hollow point bullet, unexpanded, was found on the gurney beside the body of the deceased. There was a perforating wound to the deceased that entered the right posterior shoulder, traversed the chest cavity, and exited the left chest just below the nipple. The man was wearing a heavy sweatshirt with a thick, embroidered emblem on the front. A small defect, in line with the exit wound, was found on the inside of the shirt in the area of the emblem. It was obviously an inside to outside hole owing to the outward protrusion of fibers. The hole, however, was too small for the bullet to have passed through, even with fabric stretching. What had apparently happened was the bullet had traversed the man's body and lost most of its energy but managed to still partially perforate the sweatshirt emblem. There was no visible expansion to the bullet; thus, another "pristine" bullet was born.

Sound Suppressors

The subject of sound suppressors is really not part of ballistics, but it does somewhat logically follow a discussion of the subject because sound suppression is primarily related to the rapid expansion of gases produced during the combustion of gun powder. The reader will note that the term "silencer" has not been used. That is because there is no such thing. To totally silence a firearm, one simply does not fire it.

The sounds that combine to make up the noise of discharge have a number of sources. The falling of the hammer and the working of the action are mechanical sounds associated with discharge. The rapid expansion of gases from the combustion of the gun powder, as already mentioned, comprise a major portion of the noise generated. The sonic boom created when the bullet breaks the sound barrier is an additional source of noise. Sound suppression involves stopping or reducing the report of as many of these as possible.

Any muzzle-mounted device intended to suppress sound is involved with reducing the rate of gaseous expansion and the associated sound. Other steps are required to eliminate or reduce the additional sounds that have been described. Locking the action of a semiautomatic weapon is a way of eliminating the sound of the action. Doing that means, of course, that only one shot will be possible, because locking the action eliminates the automatic reloading of the weapon. It is presumed that the reader recognizes, contrary to old classic movies, that there is no feasible way to suppress the report of a revolver because of the cylinder gap.

Eliminating the sonic boom merely requires firing subsonic ammunition. This means, of course, using ammunition with a muzzle velocity less than approximately 1100 feet per second. This ammunition is available through a number of commercial sources. A popular round for law enforcement use is the 9-mm 147-grain subsonic round. This particular round is subsonic not by design but as a consequence of maximizing the bullet weight for tactical purposes and the subsequent reduced space/reduced powder charge.

The main source of sound to be dealt with, then, is that produced by the rapid expansion of the combustion gases. Any slowing down of these gases has the effect of reducing the audible sound. For shooting reconstruction, this is where the investigator really needs to be on the alert at the crime scene. This is because there are all sorts of makeshift devises that can be used in addition to more sophisticated sound suppressors. The following discussion focuses on the various objects that the author has encountered over the years that have been placed over the muzzles of handguns and long guns in an effort to reduce the report.

Makeshift Sound Suppressors

- Two-liter plastic soft drink bottle (empty)
- Two-liter plastic soft drink bottle filled with fiberglass insulation
- Two aluminum beer cans duct-taped end to end
- Loaf of French bread
- Potato
- Pillow
- Towel
- Blanket

Perhaps surprisingly, all of these served to reduce the audible report to some extent. Both the loaf of French bread and the potato basically exploded and left debris all over both the victims and the shooters.

In the case of the potato, the author noted the presence of numerous small, white fragments on the victim's shirt and eye glasses. Upon examination of the particles with a polarized light microscope, the well-known "Maltese cross" interference figure characteristic of starch was observed. This observation prompted the use of the starch–iodine color test for which a positive response was obtained. At this point, the lead investigator was advised that there appeared to be potato fragments all over the deceased's clothing. When the investigator confronted the suspect with this, the suspect admitted to having crammed a potato onto the muzzle end of the barrel of his handgun in an effort to "silence" it. Unfortunately for the assassin, his weapon of choice was a .357 Magnum revolver, making his potato suppressor an academic point of discussion only. When asked where he came up with the concept, he replied "on *Hawaii Five-O*" (the old Jack Lord television show).

The investigator should look closely for the remnants of improvised suppressors. Cans or bottles with tell-tale holes and soot deposits should be collected for laboratory examination. Any trace evidence that appears to be out of place or otherwise questionable needs to be collected and evaluated. Soot deposits on pillows, towels, blankets, etc., are a good indication that an attempt to reduce the report was made, especially when accompanied by bullet holes.

The use of more sophisticated suppressors is usually revealed by an examination of the fired bullets. Commercially produced and home-built suppressors of more sophisticated design often use baffles and disks that the bullet must pass through. These frequently leave tool marks along the bearing surface of bullets fired through them. These tool marks are frequently reproducible, allowing the determination that the bullets have come in contact with the same object.

Case Studies

Case 1. A Homicide Case Involving a Suppressor ("Silencer")

The author was requested to reconstruct a triple homicide in which all three victims died of multiple gunshot wounds. Fired .22 long rifle cartridge cases were recovered at the scene. These cartridge cases had a head stamp identified as Fiocchi, an Italian ammunition manufacturer. At autopsy, the pathologist recovered nine .22 long rifle bullets. Each of the six intact bullets recovered (three were severely distorted) bore an area of longitudinal tool marks on the bearing surface. A tool mark comparison revealed that each of these bullets had been marked as a result of contact with the same object. These marks were inconsistent with having been produced by the interior surfaces of a gun barrel. The class characteristics of the bullets (number/widths of lands and grooves and direction of twist) included those of Ruger MK I and MK II pistols (Figure 17.28).

A suspect was developed and a search warrant was issued for his residence specifying that the search was to include any .22 caliber weapons and ammunition, associated components, materials, and accessories and/or documents pertaining to such items. The search warrant also listed suppressors, suppressor components, and/or documents pertaining to suppressors, based on the autopsy bullet examination results. As a result of the search effort, the following items were recovered:

1. Receipt for the purchase of a case of Fiocchi subsonic .22 long rifle cartridges.
2. Receipt for the purchase of a Ruger MK I semiautomatic .22 pistol.
3. Factory advertising flyer that included listings for tubes for making suppressors (Figure 17.29).

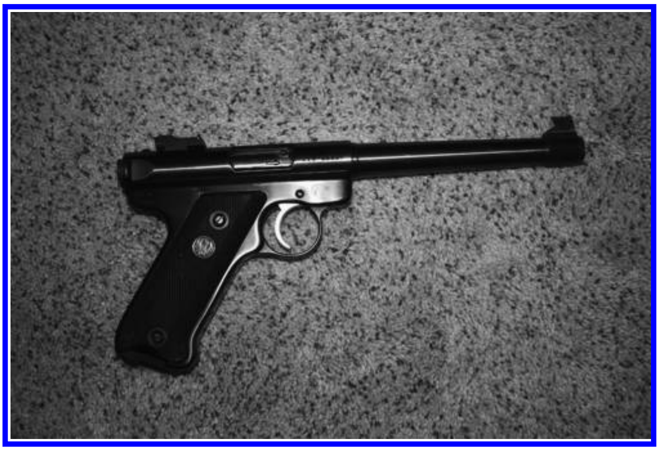


Figure 17.28 Ruger MK II semiautomatic .22 pistol.

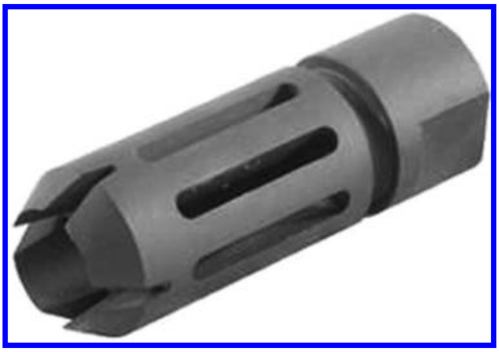


Figure 17.29 Legal Ruger flash suppressor (not to be confused with a sound suppressor).

No weapon was ever recovered nor were any subsonic Fiocchi rounds or any suppressor components. There was no way to determine that the fired bullets and cartridge cases were actually from a subsonic round. As it turned out, the defendant had owed one of the deceased several thousand dollars and was overdue on paying. The other two victims were probably at the wrong place at the wrong time as no link was ever established between either of them and the defendant.

This was a circumstantial case in every respect: there was no weapon recovered and there was no way to put the defendant at the crime scene, although he did have the opportunity to have been there and could not irrefutably prove he was elsewhere. Somewhat surprisingly, he was convicted of capital murder and given three death sentences. Obviously, the jury felt that the fact that there was documentation of the defendant having purchased a Ruger MK I pistol, the general rifling characteristics of which were the same as those on the bullets from the victims, along with having purchased subsonic ammunition and displayed an apparent interest in suppressors was sufficient to conclude that he was guilty beyond a reasonable doubt.

Case 2. A Case Requiring External Ballistics Study

A man was arrested and charged with capital murder as a result of an officer being shot and killed following a chase in which the suspect allegedly stopped, exited his vehicle, and fired two shots at the officers' vehicle from approximately 217 yards away with a 30-30 rifle with only iron sights and at night. Relevant facts associated with the case are summarized in the following list.

1. The suspect weapon was a Marlin 30-30 lever-action carbine (no scope).
2. The ammunition allegedly used was Remington 150-grain Core-Lokt®.
3. The weapon belonged to the suspect's son who lived at home.
4. Two fired cartridge cases identified to the carbine were found in a field 217 yards from the location of the police cruiser.
5. The police cruiser was parked uphill from the alleged shooter position with its emergency lights on.
6. Allegedly, both officers were inside their patrol vehicle with both front door windows partially down.
7. It was "pitch black" outside (night).
8. There was a 10 mph crosswind.

9. The suspect was believed to be intoxicated.
10. The first shot allegedly passed through the open portions of the front windows, the surviving officer stating he "heard the shot and then a bullet whizzed by."
11. The second shot allegedly hit the officer seated behind the wheel in the left eye, the bullet exiting through the window opening.
12. Neither bullet was recovered.
13. There was a bullet strike in the hood of the patrol car that resulted from the officer on the passenger side exiting the patrol unit and "returning fire."
14. When responders arrived, the dead officer was seated on the ground outside the patrol car with his back against the patrol car rear driver's side door.

Considerations in this case:

1. Uphill shot in the dark 217 yards away with a presumably unfamiliar rifle with no scope and a crosswind by a presumably intoxicated shooter firing off-shoulder and placing two shots through openings of about 10 × 28 inches in windows about 66 inches apart.
2. There was no identifiable impact spatter from the fatal perforating head wound found in the patrol car either on the center console or on the officer allegedly seated in the passenger seat.
3. The surviving officer stated he fired multiple shots across the hood of the patrol car (one striking the hood) with his 9-mm service pistol after exiting the patrol car following the two shots.
4. No bullets were recovered.
5. The combination of a small target, shooting uphill, and having a crosswind required knowing the rifle and ammunition characteristics very well.

The Prosecution Theory

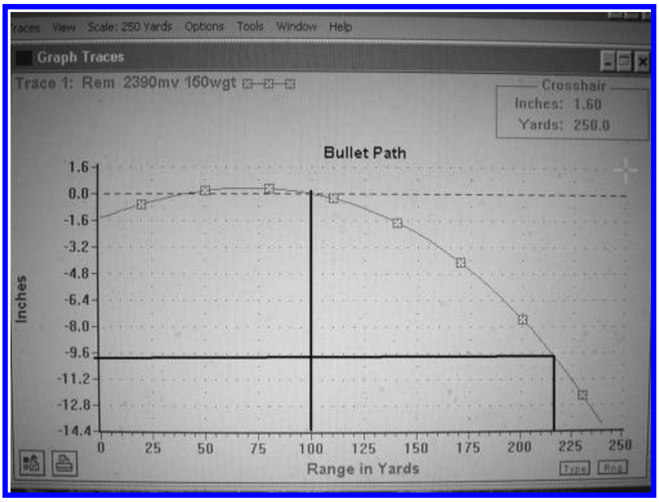
Given the obvious unlikelihood of someone being able to make such a shot not only once but twice in rapid succession, the prosecution theory was that the defendant must have been aiming for the overhead emergency lights on the police cruiser, thus providing for the distance, elevation, and cross wind.

The Defense Theory

Based on a combination of shot difficulty, lack of blood spatter inside the patrol car and on the surviving officer, and the shot fired into the hood of the patrol car, the defense theory was that this was a case of friendly fire (i.e., both officers exited their patrol car and the officer on the passenger side fired the fatal shot through the head of the other officer). Furthermore, the fired cartridge cases found at the scene could not be "dated" as to when they might have fallen there (i.e., the son might have fired shots at some earlier time and the cartridge cases had nothing to do with this particular incident).

The Trial

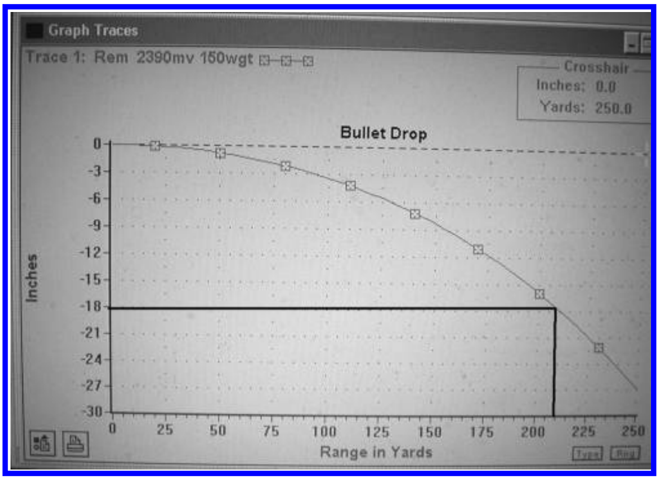
At trial, the following images (Figures 17.30 and 17.31) were shown to the jury to help explain the complexity of someone making not one but two shots through such a small opening from such a long distance at night with an unfamiliar firearm while likely intoxicated



Trace 1: Rem 2390mv 150wgt

Crosshair
Inches: 1.60
Yards: 250.0

Figure 17.30 Remington round bullet path.



Trace 1: Rem 2390mv 150wgt

Crosshair
Inches: 0.0
Yards: 250.0

Figure 17.31 Remington round bullet drop.

(a witness testified the defendant had consumed six beers in the 2½-hour period prior to the shooting).

After the pathologist testified that the shot to the deceased's head was typical of a "high-powered rifle, not a handgun," Figure 17.32 was used to illustrate that the velocity of a 9-mm handgun bullet such as the 125-grain Sierra that the surviving officer had been firing was not drastically different from that of a 150-grain 30-30 bullet at 217 yards.

After a fairly short deliberation, the defendant was acquitted of capital murder by the jury. It no doubt was beneficial to the defense effort that many of the jury members were deer hunters and understood the nuances of ballistics in the case. Of particular note had been the testimony of the surviving officer who testified to having "heard the first shot and then felt the bullet whiz by" his face. As anyone familiar with firearms knows, the bullet would have preceded the sound rather than followed it.

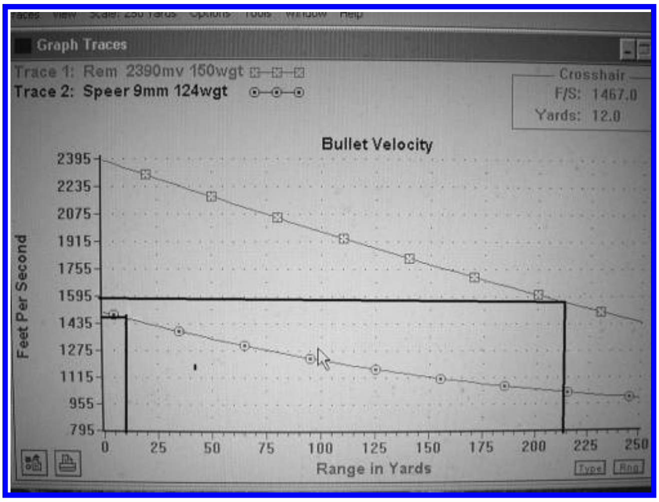


Figure 17.32 Comparison of velocities of 9 mm (at 10 yards) to 30-30 (at 217 yards).

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Firearm/Ammunition Reference Collections, Databases, and Software

18

Firearm/ammunition reference collections are a vital part of law enforcement firearm identification units. These collections allow direct inspection of the items for comparison to questioned items found at shooting scenes or recovered at autopsy. An important additional benefit of firearm reference collections in particular is the ability to acquire replacements for missing or broken parts for weapons suspected of having been used in shootings. The identification of the weapon and ammunition used in a shooting is a fundamental part of shooting reconstruction. Some of the most complete reference collections, as would be expected, are maintained at the largest police agencies. Those reference collections number in the thousands, necessitating rather involved inventory control and security considerations.

Numerous databases are available to assist the individual tasked with reconstructing a shooting incident. These databases include both stand-alone databases and mainframe-housed databases available via the Internet. As is standard with any database, regular upgrades are required in order to remain current. Many of the mainframe-housed databases are accessible to law enforcement only.

All of the various databases that are available offer the investigator the capability to rapidly search out needed information for shooting reconstruction purposes. These databases include information that would otherwise be difficult and time consuming to run down.

Weapons/Ammunition

The most extensive firearms reference collections in the United States are, as already stated, maintained by some of the largest law enforcement agencies. The reference collections of the Los Angeles County Sheriff's Office, New York City Police Department, the Federal Bureau of Investigation, and the Bureau of Alcohol, Tobacco, Firearms, and Explosives number in the thousands and include multiple examples of virtually every commonly encountered firearm as well as numerous examples of rare and unusual weapons. Similarly, large collections of ammunition components are also maintained by these agencies. Local law enforcement agencies involved in the reconstruction of a shooting can usually contact their state agency or either the FBI or the ATFE regarding ammunition or firearms identification questions that necessitate the availability of a reference collection. This information is available to law enforcement agencies only.

Scott Doyle of the Kentucky State Police has, without a doubt, the most impressive, comprehensive, and useful public access website relating to firearms identification. In addition to having a wide variety of firearms identification data and interactive components, Scott has compiled a database of trigger pull information that is available to anyone by going to Scott's website, http://www.firearmsid.com. This information permits comparison of trigger pull test results to those found for similar weapons in the database. This gives the examiner a way of assessing how well the obtained results fit into "the general population" and, thus, assess the significance of an apparent departure from a manufacturer's specified value.

Scott has also compiled a general rifling characteristics file that may also be accessed through his website. Similar to the old FBI Crime Lab Information System (CLIS) General Rifling Characteristics (GRC) file, this file consists of rifling characteristics for a large number of weapons. This database is a useful alternative to the no longer available CLIS GRC file. Scott has received numerous well-deserved awards for his outstanding contributions to the field of firearms identification and shooting reconstruction through his website.

The Association of Firearm and Tool Mark Examiners (AFTE) has a website (http://www.afte.org) with links to valuable firearms information and databases that is accessible to members only. By going to the member's section and entering a password, these links may be found. Two databases of particular utility for shooting reconstruction are the serial number search database and the shotshell wadding search database.

Additional databases of value for shooting reconstruction found on the AFTE website include:

- Firearms cross reference search
- The AFTE glossary
- *AFTE Journal* search
- Recalls and warnings section
- Safety bulletins
- Potpourri

The firearms cross-reference search provides cross references for weapons manufactured for various distributors and bearing different markings but all from the same manufacturer, or weapons with the same markings but from different manufacturers. This can be invaluable in trying to identify a particular weapon as to its manufacturer.

The AFTE glossary is a compilation of firearms and ammunition terms that are generally accepted in the field of firearms identification. It is important that the investigator use the correct terminology in the preparation of written reports and in giving court testimony and at depositions. This reduces the chances for confusion and projects a more professional image on the part of the presenter.

The *AFTE Journal* search permits the user to do a literature search to assist in understanding or reconciling issues associated with shooting investigations by being able to quickly access published works in various general and specialized areas of shooting incident reconstruction.

The recalls and warnings section consists of postings of factory warnings and warnings from other examiners who have encountered concerns relating to the use of certain weapons and ammunition. This information can be important when attempting to determine whether accidental discharge is involved in a shooting incident. This can also be important when evaluating the possibility of other safety issues. The same areas of interest are associated with the safety bulletins section of the website.

The "potpourri" section, as the term would imply, is a collection of generally unrelated, esoteric considerations involving firearms and tool marks. From time to time, the investigator may find something pertinent to a shooting under investigation here.

Although the members section of the AFTE website and the above-described sections are only available to AFTE members, a non-AFTE member of law enforcement can usually have the benefit of this information as a result of contacting their local, state, or federal firearms unit and requesting assistance. Most firearms units have AFTE members who are usually glad to assist by doing the needed searches.

Another resource for information relating to firearms and ammunition components is *Firearms Guide 5th Edition*, which was introduced at the 2014 SHOT Show. This firearms reference software contains image viewing tools that allow close inspection of 59,000 firearms, airguns, and ammunition from 705 manufacturers. This makes searches through reference texts for full views and schematics a thing of the past. This software may be purchased online at http://www.firearmsguide.com. INTERPOL offers a Firearms Reference Table to authorized users via INTERPOL's restricted website. This site contains more than 250,000 firearm references and more than 57,000 firearm images.

Longtime AFTE member and advisor George Kass of Okemos, Michigan, is the undisputed "go-to guy" for information and exemplars of ammunition. George does business under the name Forensic Ammunition Service. He specializes in the unusual and the obscure. Additionally, George has authored a text on the identification of rimfire ammunition head stamps (*Rimfire Head Stamp Guide*). George may be contacted online at forammo@aol.com.

Most of the major weapons and ammunition manufacturers have websites that offer the investigator a wealth of information. For example, the Glock Firearms Corporation website, http://www.glock.com, contains pertinent data on all Glock firearms, and the Federal Ammunition website, http://www.federal.com, contains ballistics data and other information on all of their products.

In summary, the absence of a firearm in a shooting incident requires the investigator to attempt to determine what type firearm may have been used. This becomes the first shooting reconstruction hurdle in a so-called no gun case. When fired bullets and cartridge cases are recovered, an examination of their markings may allow a database search that, in turn, produces a list of potential candidates. These candidates may be then viewed and examined with the aid of commercially available databases or databases made available to law enforcement agencies by the AFTE, ATF, FBI, INTERPOL, and others.

Vehicle Information

It is often necessary to have information regarding vehicles involved in shooting incidents that either cannot be readily obtained, or was not a consideration at the time of the initial investigation but subsequently becomes an issue. In these cases, it is possible to either locate a similar model for examination or to obtain the necessary data from the manufacturer. Most new car dealership service departments can access this information and are usually very cooperative in providing it to law enforcement. There are some online for-fee services as well.

In a case the author was involved in that was previously described, there was an issue concerning the turning radius of a Chevrolet extended cab pickup truck. Specifically, an officer had been standing beside the driver door attempting to question a possible drug user who was inside the vehicle in the driver seat. According to the officer, the driver started the vehicle, turned the wheel toward him resulting in the officer firing shots as a result of "being in fear for his life." In reviewing the shooting, it was necessary to know the turning radius of the truck. This information was acquired by contacting General Motors. In this particular instance, the information was provided by the parts department staff at a local dealership. The data were confirmed by testing with a similar truck. The investigator can usually obtain similar information from the same type of source whenever necessary.

There are a number of software packages that include both specific and generic vehicle images/diagrams. Whenever shots have been fired into vehicles, it is important to prepare diagrams that show both bird's eye views and profile views of the vehicle with trajectories extended out to the maximum possible shooter position. This is usually determined on the basis of shooter height and the reported position of the weapon. Positions that require the shooter's hands to be extended above the head, for example, would be excluded, barring any specific information to the contrary. A sample of the vehicle diagrams that can be produced using Crime Zone software by CADZone is shown in Figures 18.1 through 18.3.

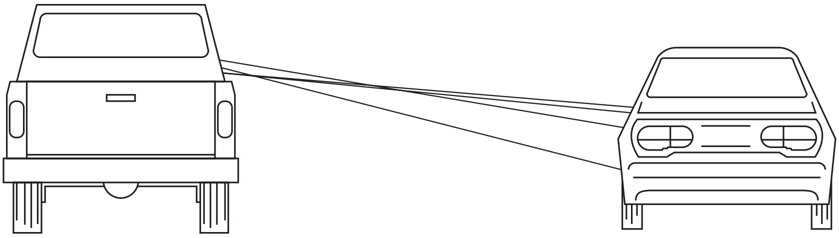


Figure 18.1 CADZone vehicle sketches.

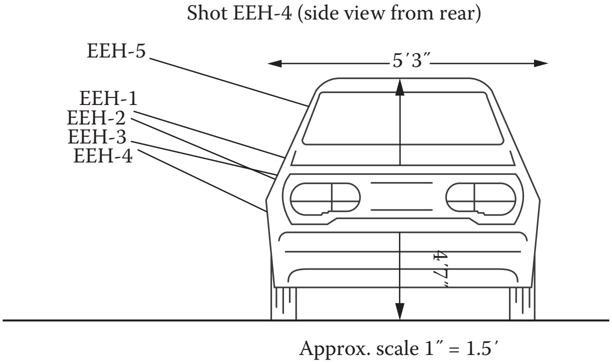

Shot EEH-4 (side view from rear)
EEH-5
5′3″
EEH-1
EEH-2
EEH-3
EEH-4
4′7″
Approx. scale 1″ = 1.5′

Figure 18.2 CADZone side view with approximate muzzle to target distances shown.

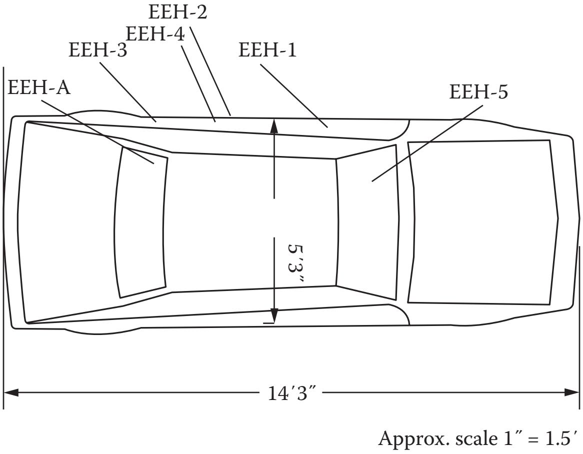

EEH-2
EEH-4
EEH-3
EEH-1
EEH-A
EEH-5
5′3″
14′3″
Approx. scale 1″ = 1.5′

Figure 18.3 CADZone top view with approximate muzzle to target distances shown.

This software also includes scene diagrams as well as human figures, weapons, and a wide variety of other objects. The software is marketed by CADZone, Inc. (Beaverton, OR, USA; company website: http://www.cadzone.com). Vehicles, human forms, and other objects may be sized to fit the particular shooting involved. The human forms may be set to virtually any position as either a bird's eye view or a two-dimensional (2-D) profile and any position in 3-D. Two examples of the human forms that can be generated appear in Figures 18.4 and 18.5.

The CADZone software is powerful but somewhat user unfriendly. It does require rather extensive training in order to develop total proficiency. It lacks the intuitive nature of other software, but it is capable of producing outstanding diagrams once some degree of proficiency has been attained. The admittedly "low-tech" diagrams, although quite functional, leave a great deal to be desired in this age of high-definition color 3-D imaging. Figures 18.6 and 18.7 illustrate the use of available software.

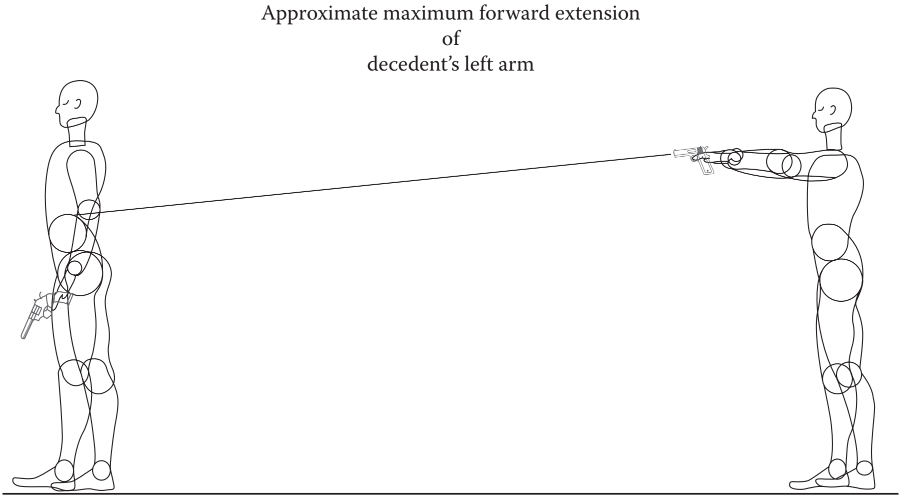


Figure 18.4 CADZone human forms.

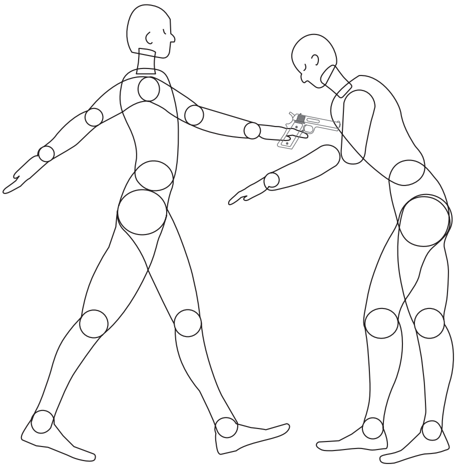


Figure 18.5 CADZone human forms.

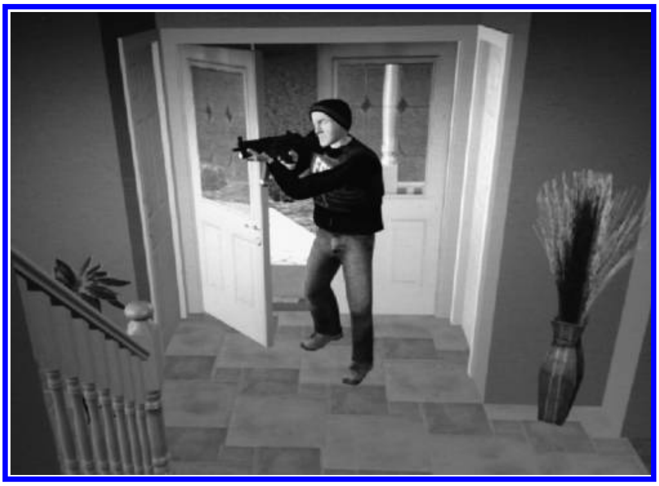


Figure 18.6 3-D figure.

Figure 18.7 3-D vehicle.

There are advantages and disadvantages to both types of representations. Thus, there is justification for having access to both for purposes of representing the reconstruction of shooting incidents.

Architectural Information

It is sometimes important to be able to determine the standard architectural dimensions for various structures, streets, sidewalks, curbs, and so forth, especially when access to the scene is limited or impossible. John Wiley & Sons, Inc. offers an architectural graphic standards CD-ROM that contains most of the information pertaining to these things. Additionally, human forms are included that portray both male and female forms. Vehicles are included as well. From this information, one can determine the expected dimensions, angles, and spatial arrangement of a wide variety of forms based on standard architectural measurements. Naturally, there is no substitute for obtaining the desired dimension from the actual item in question. When this is impossible for whatever reason, this type of database is invaluable for shooting reconstruction purposes. The reality is that it is seldom possible to anticipate each and every measurement that may subsequently be needed in the reconstruction effort.

Site-specific information is also available from city building code offices, street departments, state highway offices, and architectural firms and civil engineers. Building plans are usually on file with building code offices, and architectural firms and civil engineering firms maintain blueprints for structures and projects that they have designed.

Weather and Meteorological Data

The reconstruction of a shooting, particularly when it occurs outdoors, often has lighting considerations. Officer-involved shootings that take place under low-light conditions often have issues concerning whether the officer could have seen the suspect well enough to discern that a weapon was in his hands. Ambient lighting conditions become critical in these instances. Obviously, the difference in available light on a clear night with a full moon and a cloudy night with no moon is considerable. Accordingly, any reconstruction or reenactment effort must take this into account.

The fact that precipitation occurred may have an impact on the reconstruction. The author worked on a case where a glove had been worn during a shooting. The glove had been tossed to the ground outside the building where the murders took place and remained undiscovered for 2 days. During that period, it had rained and the glove had been exposed to that rain. As it turned out, a question arose as to the number of shots fired by the suspect while wearing the glove. In order to attempt to establish the number of shots, the glove was to be analyzed for lead, barium, and antimony by the no-longer-used technique of flameless atomic absorption. The question was whether one shot or four shots had been fired with the glove on. To carry out the testing, it was necessary to know, as closely as possible, how much precipitation had fallen on the glove in order to set up a simulation. This was because it was anticipated that the precipitation could have washed away some of the residue. Fortunately, this information is readily available from the U.S. Weather Service National Climatic Center in Asheville, North Carolina. Their contact information is as follows:

U.S. Weather Service
National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801-5001
Phone: (828) 271-4800
E-mail: ncdc.info@noaa.gov

Two useful websites—one for lunar data and the other for climatological data—are http://www.moonpage.com and http://www.WeatherForYou.com. The lunar site shows images of the moon for each day of the month and provides descriptive details. The weather site provides detailed weather information similar to the U.S. Weather Service.

The author reconstructed an officer-involved shooting in which the officer had shot a suspect based on the officer's perception that the suspect had a gun in his hand. The shooting had taken place at night out in the street in a residential area. A check with the U.S. Weather Service National Climatic Data Center revealed that there was a full moon on the night of the shooting and that the weather had been partly cloudy. To establish what sort of visibility the officer may have had and, in turn, to determine whether the shooting had been justified, a reenactment was carried out. As ambient light was the main issue, the reenactment was scheduled for the anniversary date of the shooting. This was possible because the reenactment was in response to a civil suit against the police department over the shooting and nearly a year had passed since the shooting had taken place.

Other lighting issues included streetlights and lights in surrounding residences. The cloud cover was clearly not something that could be controlled; however, it happened that it was also partly cloudy on the anniversary night. By having the correct meteorological data, the reenactment was conducted under conditions that closely duplicated the actual shooting. The end result was that it was apparent from the reenactment that the officer would not have been able to see well enough under the scene conditions to confirm or eliminate the presence of a gun in the suspect's hands. Because the officer had stated that the suspect had extended his arms toward the officer and this had been corroborated by a witness, the shooting was determined to be justified.

In any shooting incident taking place outdoors at night, ambient lighting conditions need to be established. Crime scene photographs should be taken so as to document the lighting present. Written crime scene notes should document lighting, cloud cover, phase of the moon, and any other sources of light present.

When shooting reconstructions are required and the lighting conditions at the scene were not properly documented, the investigator must rely on data available from sources such as the U.S. Weather Service and the street department. Street department records should be consulted to establish whether there are any pertinent records relating to streetlights in the area. For example, a record of a streetlight being repaired shortly after a shooting would suggest that the light may have been out at the time of the shooting. On the other hand, the lack of repair history on streetlights in the immediate area of a shooting would tend to indicate that the lights were working at the time of the shooting unless there was some reason to expect otherwise (i.e., an established pattern of not replacing broken lights in a particular area).

When photographic documentation of streetlight locations is inadequate and it is inconvenient or impossible to return to the scene, all is not lost. Street view apps are available that permit the investigator to electronically "return to the scene" and search for street lights. One particularly useful site that the author has used in several instances is http://www.showmystreet.com. Another site that can provide similar information is Google Earth (street view). Once again the investigator must be cautious about relying on the information without verifying the date the images were produced. One way this can be easily estimated is by using the same site to visit a location with objects that fix approximate dates by their presence (the author goes to his own property via the site being used to verify the approximate date of image capture). Examples of street views are shown in Figures 18.8 through 18.10.

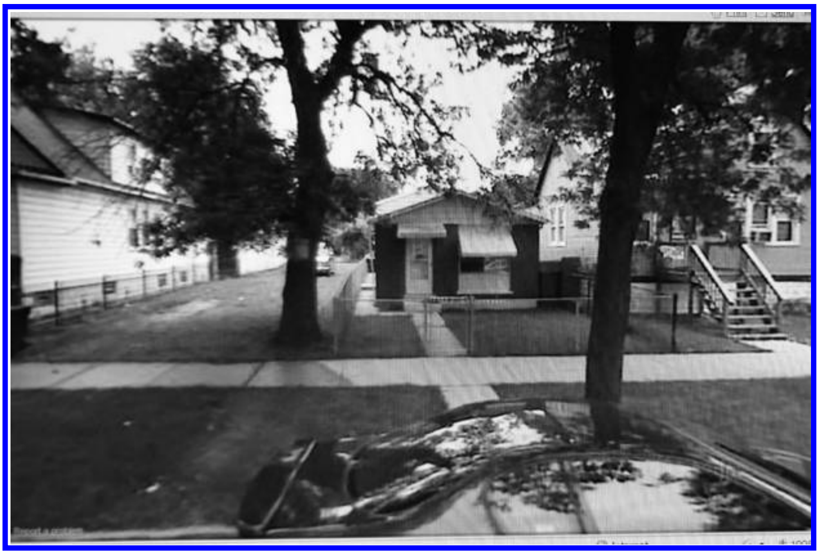


Figure 18.8 Show My Street image 1.

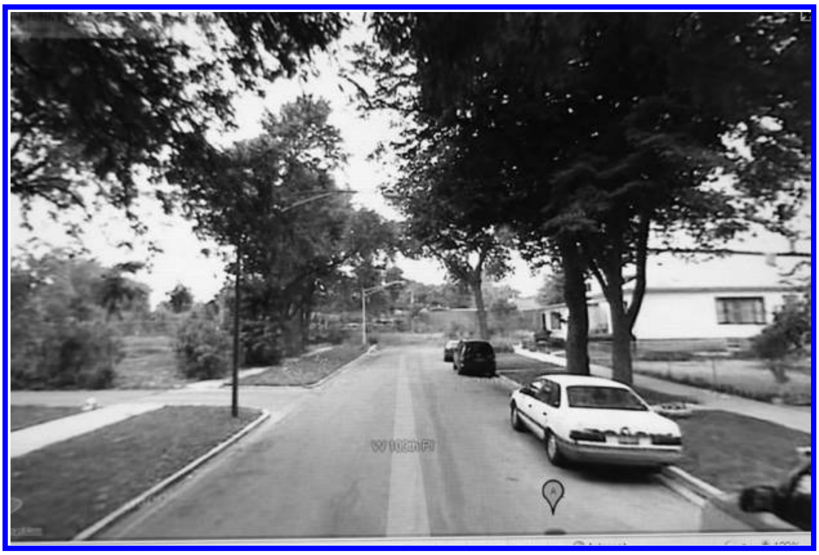


Figure 18.9 Show My Street image 2.

Imagery

Panorama Technologies Corporation Ltd. markets a software known as Crime Scene Virtual Tour. This is based on 360° panoramic images that integrate crime scene images, an interactive map, texts, audios, links, and thumbnails into a virtual crime scene tour that allows the viewer to control the movement through the scene, zoom in on any object, and turn images to view them more clearly. This allows investigators and juries alike to "go back to the scene." Images and relevant text are viewed at the same time. Through the links and thumbnails, additional pertinent information may be accessed along the way. The software requires only standard photographic knowledge to operate, and no special training is

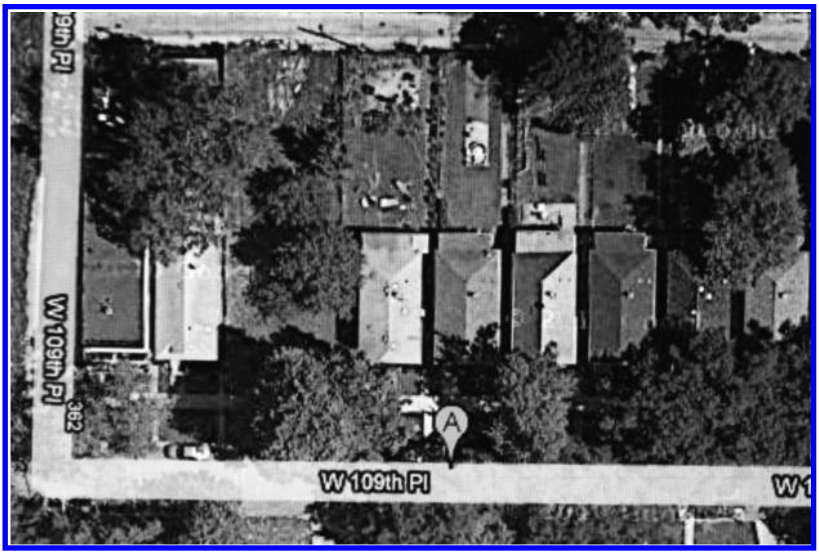


Figure 18.10 Show My Street image 3 (satellite view).

required. A sample virtual tour of a crime scene may be accessed by going to the company's website, http://www.easypano.com. This software format has been used by a number of agencies in training investigators in addition to utilizing it for courtroom presentation.

There are numerous commercial outfits that can provide computerized animations as still images that may be tailored to the needs of the investigator. One need only search the Internet to find such service providers.

Crime Scene Software

A variety of excellent software packages are available for producing crime scene diagrams. Those that have already been mentioned include Crime Zone, 3D Eye Witness, and Visio. An excellent software for accident scene diagramming is marketed as Crash Zone, a companion product to Crime Zone (both are CADZone products).

Another software product for crime scene drawing is Diagram Studio by Gadwin Systems, Inc. According to the manufacturer, the software is compatible with graphics printers and plotters, and only requires 14 MB of hard drive space. Floor plans, street and directional maps, and directional routings are all producible with this software. It comes with complete flowcharting templates, diagramming templates, and block diagrams. Linked text labels may be added, and libraries may be accessed or custom created. Sample diagrams may be viewed and additional information obtained from the company website, http://www.diagramstudio.com.

The ultimate crime scene diagramming tool, as described in Chapter 6, is a 3-D laser scanning system that maps the crime scene using a laser and downloads the data into software expressly designed to generate complete 3-D diagrams. Leica Geosystems manufactures a variety of 3-D laser scanning systems. Tony Grissim is the public safety and forensic account manager for Leica Geosystems and can be contacted at tony@lgshds.com.

The wide variety of hardware and software provides the shooting reconstructionist with many different options. The reader is encouraged to explore the possibilities to determine what best fits both their needs and budget. Most of the software may be downloaded in trial version off the Internet. This allows one to develop at least some familiarity with the various offerings before purchase. As always, references from other practitioners can save a lot of time and frustration when trying to make a decision as to what software or hardware to purchase.

Suggested Readings

http://earth.google.com/, accessed February 23, 2015.
http://firearmsid.com/, accessed February 23, 2015.
http://www.afte.org/, accessed February 23, 2015.
http://www.cadzone.com/, accessed February 23, 2015.
http://www.diagramstudio.com//, accessed February 23, 2015.
http://www.easypano.com//, accessed February 23, 2015.
http://www.federal.com/, accessed February 23, 2015.
http://www.glock.com/, accessed February 23, 2015.
http://www.moonpage.com/, accessed February 23, 2015.
http://www.showmystreet.com/, accessed February 23, 2015.
http://www.WeatherForYou.com//, accessed February 23, 2015.

Report Writing, Demonstrative Evidence, and Courtroom Presentation

19

Report Format

Most police agencies have a standard reporting format that they use. This format does not always allow a lot of latitude as to how the written report will be structured. One of the biggest drawbacks, in the author's opinion, to this is that each section of the laboratory typically writes a report concerning only the particular evidence that they examined, a separate report is written on the crime scene investigation, and other reports are written on the follow-up investigation. Although this is an entirely appropriate approach, it is the lack of a summation report that often leaves it up to the reader to attempt to collate all the results obtained and come up with overall conclusions.

It is this writer's firm belief that there should be a single document that collates and summarizes all the findings of the various laboratory sections, the results of initial and follow-up investigations, and the autopsy report. This report should be a stand-alone document that its reader can use to understand what physical evidence is being described, where it originated from, what the test results were, and—most importantly—what the results imply. Relationships between various items of physical evidence, although examined by different crime laboratory units/analysts, should be described and explained. The ties to the investigative evidence should be included, as should the findings articulated in the autopsy report.

Admittedly, this concept of an overall summation report presents a problem from the standpoint of who should write it. The lead investigator most frequently does so in those departments that use this approach. In officer-involved shootings, as part of the administrative investigation, a shooting review board of some sort usually issues a summation report. One of the most important aspects of issuing a summation report is that it ensures that a review of all aspects of the shooting investigation is done. This approach minimizes the chance of evidence or investigative aspects "slipping through the cracks."

In a case the author reviewed involving a questionable shooting death, it was suspected that the handgun involved had fallen to the floor and a blow to the hammer had caused it to discharge. The crime scene investigator had noticed some fibrous material adhering to the hammer spur and had requested that the trace evidence section examine and identify the fibers. The investigator failed to get a control sample of carpet fibers at the scene. The trace evidence analyst issued a report stating that fibers were present and left it at that. No summation report was issued in the case. Had someone written a summation report, after reviewing all aspects of the case, perhaps this "glitch" would have been recognized and corrected.

The following is an outline of a suggested format for preparing a summation report on the reconstruction of a shooting.

Suggested Summation Report Format

1. Introduction—a brief synopsis of the incident that includes when and where the shooting took place and the general circumstances that were involved, including main participants/witnesses names and addresses.
2. Documentation—this section of the report lists all of the written and photographic documentation that was reviewed and relied upon for forming opinions in the incident.
3. Physical evidence examined—this section should list and describe all of the physical evidence examinations that were conducted (including vehicle and scene examinations, shot accounting, and trajectory analyses) and summarize the findings (include supporting images, graphs, and/or diagrams).
4. Reenactment and other related scenario testing that was done—any reenactments and other related scenario testing that was done should be detailed and illustrated as appropriate with images, graphs, and/or diagrams.
5. Results of investigative efforts—all investigative results that were obtained should be described and tied to supportive physical evidence explained in detail.
6. Opinions—this section should put forth opinions derived from all the various aspects of the shooting investigation/reconstruction effort.
7. Conclusions—this section proposes the probable scenario and/or sequence of events for the shooting (whenever feasible).
8. Attachments—individual reports relied on may be attached, along with other supporting documents.
9. Disclaimer—as a general practice, it is important to note that the opinions expressed in a report are based on the information that was provided before the report was written (see example below).

Note: The opinions expressed herein were based upon the information that was available at the time of this writing. Should new or different information be forthcoming, the right to modify these opinions accordingly is hereby reserved.

The disclaimer may be appropriately inserted at the beginning of the report, the end of the report, or in both locations.

10. Preliminary reports—it is sometimes necessary to issue preliminary reports that recognize that the investigation is ongoing.
11. Supplemental reports—when the need arises (e.g., receipt of new or different information), a supplemental report is required.

Exactly how to incorporate photographic images into the body of the report depends primarily on what the images are intended to show and what format best accomplishes this. Although inserting images into the body of the report allows instant visual access, the small size required to do so may detract from the overall effectiveness. Placing full-sized images at the back of the report as an attachment facilitates maximum visual perception—the only minor drawback being that the reader must flip back and forth between the body of the report and attached images.

Proposed scenarios should be presented as “probable” or “likely” rather than as absolute fact, as discussed in Chapter 1. When a proposed scenario fits the statements of witnesses and/or participants, this should be articulated in the conclusions. Likewise, when the scenario that has been formulated is at odds with witness/participant statements, this needs to be stated as part of the conclusions.

One of the author's longtime friends and colleagues has applied a "fluff versus substance" test to report writing. There are reports with all substance but no "fluff," meaning illustrative diagrams, sketches, and the like. On the other hand, there are reports that amount to "all fluff and no substance." These are reports that abound with meaningless charts, graphs, and photographs that tend to stand alone rather than support any sort of meaningful conclusions. Obviously, the desired effect should be both "fluff" and substance—that is, a report that is professional in appearance as well as being visually interesting, reaches scientifically valid conclusions, and clearly articulates these conclusions through the use of relevant visual aids.

Drawings, Diagrams, and Photographic Images

Drawings, diagrams, and photographic images are an effective way to transmit information in a succinct, understandable manner. To do so, however, requires that the images and drawings be clear and concise and not "too busy." The rule for speakers regarding visual aids is to limit each slide to one main point rather than putting forth multiple points on the same slide. The same rule is appropriate for drawings and images.

Photographs for inclusion in reports and for court presentation should be of appropriate quality and format. Photographs of shooting scenes should be taken following the same rules as those for general crime scene photography with a few additions. These rules can be summarized as follows.

General Rules for Shooting Scene Photography

- Use a quality SLR digital camera with a detachable strobe (flash).
- Have a 50-mm lens, a macro lens, a wide-angle lens, and a telephoto lens.
- Have a tripod and a wireless shutter release available as needed.
- Have a variety of filters including a polarizing filter.
- Have a variety of scales in various colors, magnetic and nonmagnetic, straight and right angle.
- The first image recorded on a digital memory card should be the case identifier—this will show the time, date, location, case number, and photographer.
- A photo log should be prepared—this will show what camera and lens was used and show the camera setting (f-stop and shutter speed if in "manual" mode or specific setting if in "automatic" such as "portrait" or "close-up") for each image along with a description of the item being photographed and its location within the shooting scene.
- Begin with overall photographs, then move to specific subjects—remember the old rule of crime scene photography: you can't take too many photographs, but you can take too few—take multiple photographs of each item of interest and bracket your exposures (this can be done automatically). Examples of photographic considerations are shown in Figures 19.1 through 19.3.

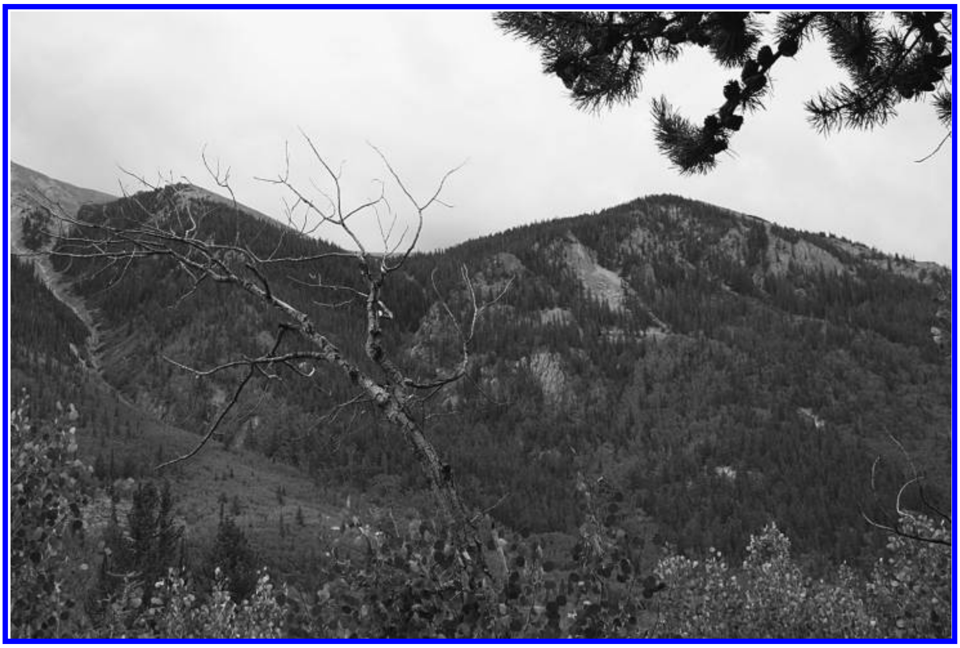


Figure 19.1 **(See color insert.)** Distant view with depth of view details (branches).

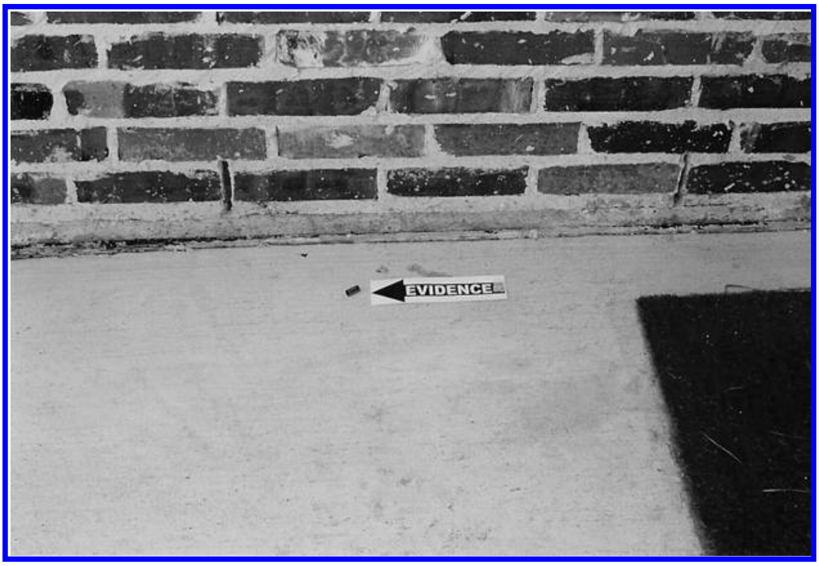


Figure 19.2 **(See color insert.)** Cartridge case—intermediate distance.

- Photograph evidence both with and without a scale present—this is to eliminate questions about scales possibly covering up evidence in photographs (Figures 19.4 and 19.5).
- Evidence should be photographed with the camera back in a plane parallel to that of the evidence whenever possible—this is to eliminate distortion and, thus, allow accurate measurements to be made from the photographs with scales present.
- Use of a tripod and a remote shutter release is recommended for any type of macro photography, footwear impressions, and latent prints—many times this will be

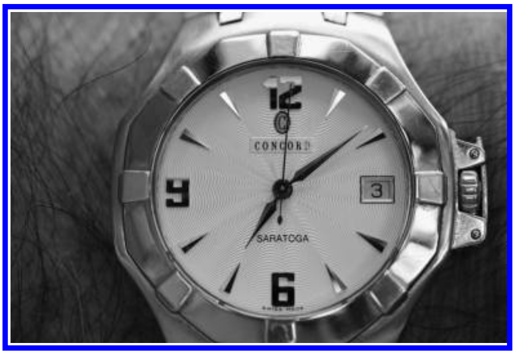


Figure 19.3 **(See color insert.)** Close-up taken with tripod and remote shutter release.

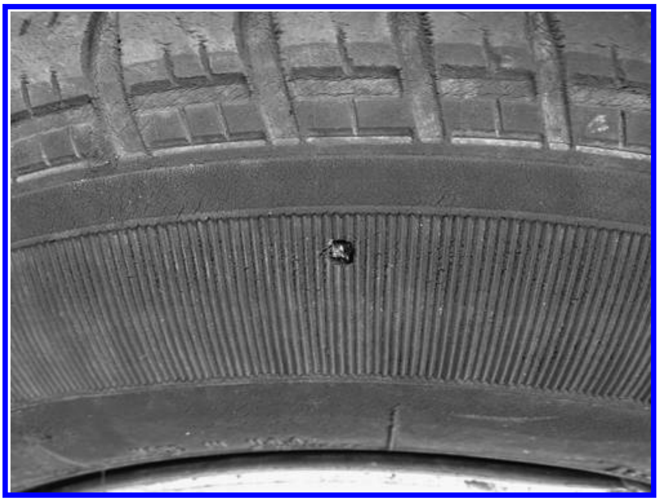


Figure 19.4 **(See color insert.)** Bullet hole in tire sidewall (no scale).

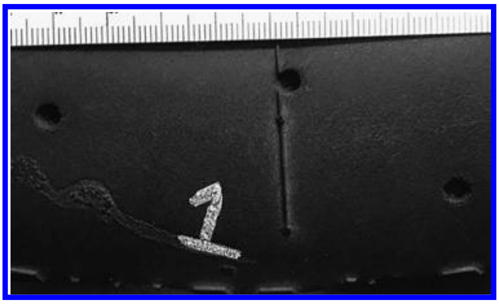


Figure 19.5 Close-up of bullet holes in tire sidewall (with scale).

impractical because of the physical constraints at shooting scenes, but it is the only way to ensure the best quality images where fine detail is important.

- Bullet holes and other evidence at the scene should be assigned a number or letter designator that is visible in all photographs and carried through in all documentation (reports)—this is the only sure system for identifying evidence and other items of interest within the shooting scene and later in the report and during courtroom presentation.

- Stick-on arrows may be included to show directionality, particularly in close-up photographs (or added later using digital imaging)—this eliminates questions as to orientation.
- Fill the frame with the subject matter while still allowing the scale and the evidence designator to show up in the image produced—photographs of bullet holes and other evidence at the shooting scene should be taken as close as possible (Figures 19.6 and 19.7).
- Oblique lighting is required for photographing bullet holes in glass—this may be accomplished with available light in some instances but usually requires shading the subject matter and then using a detachable strobe (flash) with a 4-foot sync cord (or wireless unit) held at a low angle.
- A ring flash is a useful accessory for macro photography of small evidence items such as firearms and ammunition components—a ring flash allows 360° of illumination for taking close-ups of small evidence items (Figures 19.8 and 19.9).
- Trajectory rods inserted into walls, car panels, mannequins, etc., should be photographed both from an overhead perspective and a side (profile) perspective whenever possible—the idea here is to document the *x* and *y* angular components of the trajectories represented by the rods (Figures 19.10 and 19.11).

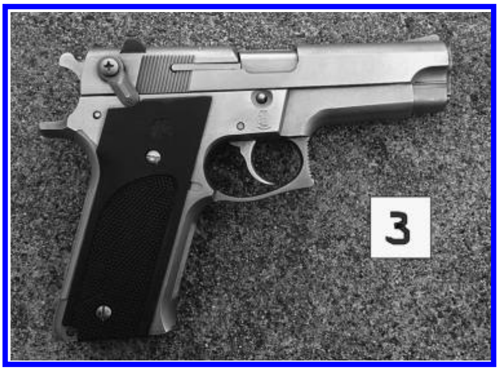


Figure 19.6 Firearm as found at the scene.

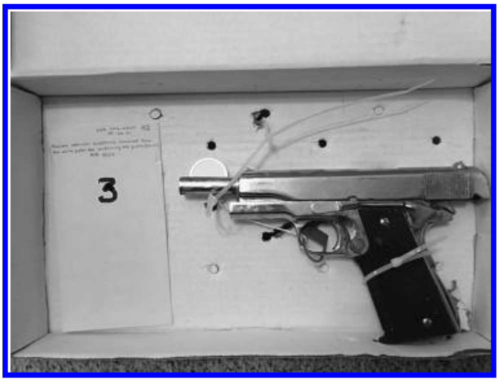


Figure 19.7 Firearm secured for transport to laboratory.

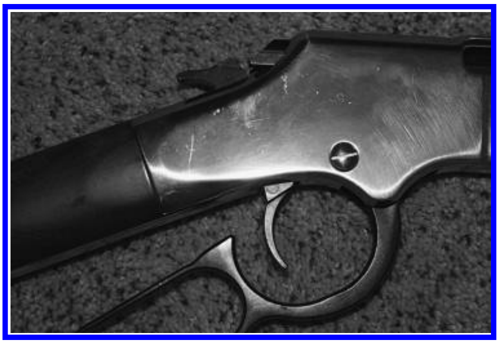


Figure 19.8 Lever action out of battery.

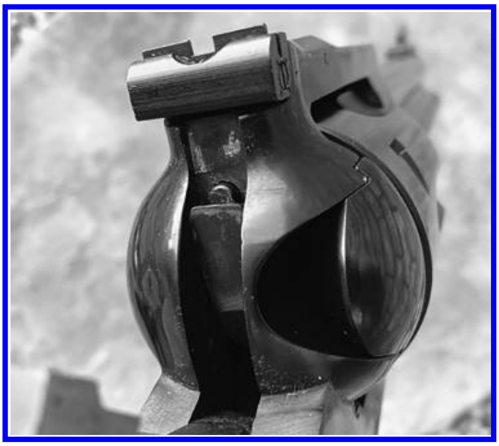


Figure 19.9 Close-up of transfer bar safety.

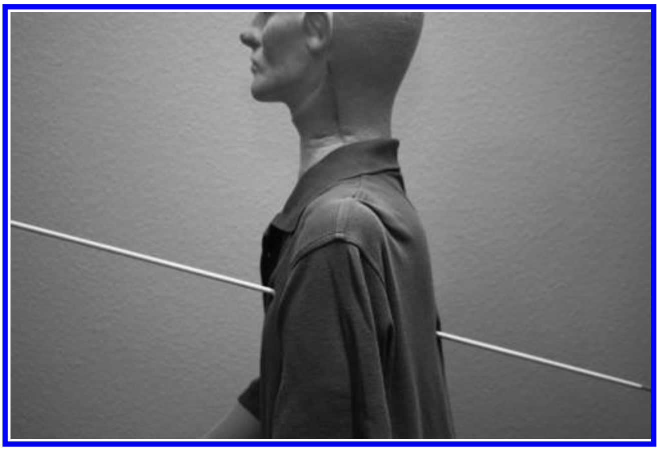


Figure 19.10 Side view of trajectory.

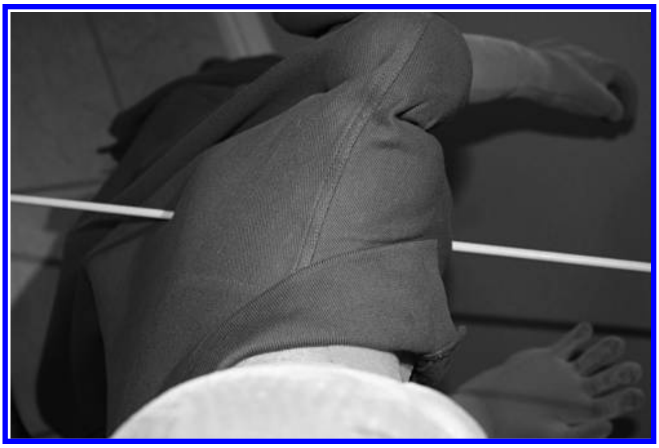


Figure 19.11 Top view of trajectory.

By following these rules, the investigator will have the best photographic documentation possible. Additionally, the ability to prepare full-scale images and enlargements will be afforded. The question as to which format, 35 mm or digital, is best will not be argued here. Suffice it to say, however, that most departments across the country have converted to digital imaging.

With regard to preparing diagrams of shooting scenes for inclusion in reports and presentation in court, the general principles of crime scene diagramming should be followed (see the following discussion).

General Considerations in Shooting Scene Diagramming

- Indicate compass direction on the diagram—typically, the northerly direction is indicated.
- Label the diagram “not to scale” if no scale is intended; otherwise, indicate the scale but label the diagram “approximately to scale”—this is done to avoid the common pitfall of having something slightly out of scale even though the diagram was presented as being drawn to scale.
- Show who prepared the diagram and the date of preparation.
- Include a legend when numerous items of evidence are to be included in the diagram.
- Use both an overhead perspective diagram and a profile perspective diagram if bullet trajectories are included (or use a three-dimensional [3-D] diagram).
- Images of the actual evidence item may be inserted into the diagram if desired and appropriate—as with inserting images into the body of a report, consideration as to the loss of detail owing to reduced image size must be given.

The use of poster-size enlargements of photographic images and diagrams can help a jury better understand the nuances of a shooting reconstruction (Figures 19.12 through 19.15). This demonstrative evidence can be especially effective when it is placed on an easel in the courtroom in view of the jurors and allowed to remain there for a significant

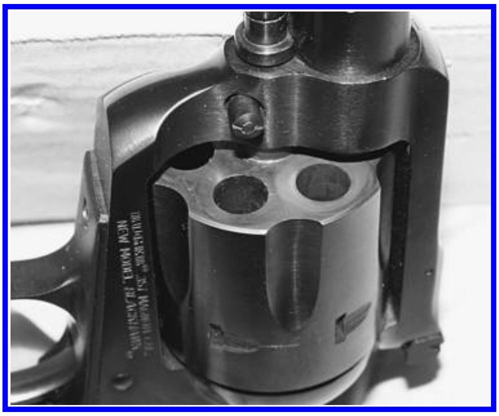


Figure 19.12 Cylinder flare (taken at the scene prior to packaging).

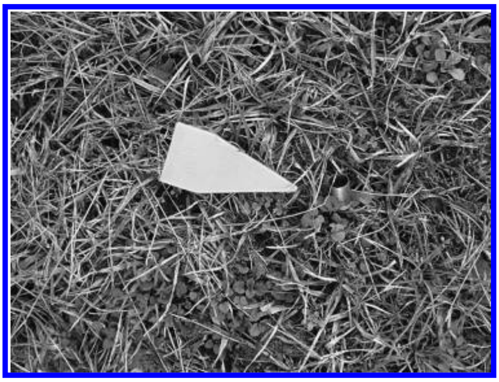


Figure 19.13 Marker added to indicate cartridge case location.

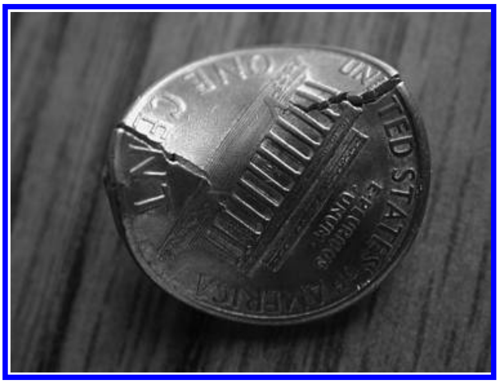


Figure 19.14 Lucky penny officer had in his pocket—deflected a bullet.

length of time or even through the entire trial. Prosecutors generally welcome suggestions from investigators as to which images are particularly relevant to the shooting reconstruction.

Computerized animation may be a consideration for courtroom presentation. The proliferation of this type of format in every aspect of society has paved the way for increased

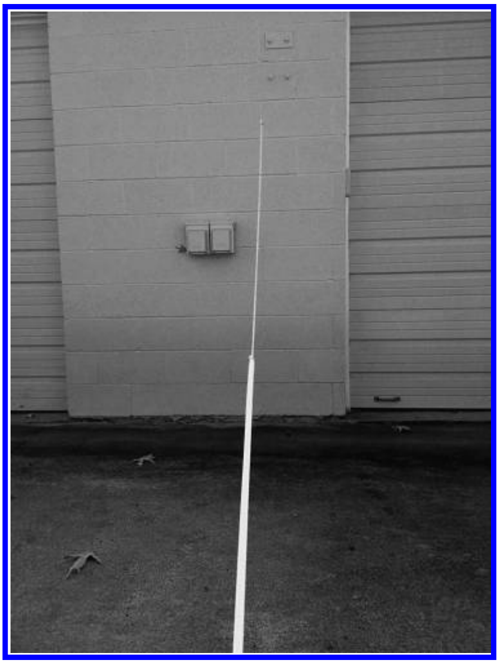


Figure 19.15 Trajectory string—camera set on black–white mode and polarizing filter used.

use in court. Juries tend to expect a "dog and pony show" thanks to all the movie and television dramas that are devoted to crime scene investigation these days. This has, admittedly, resulted in the regular inclusion of computerized animation in court proceedings. Examples appear in Figures 19.16 and 19.17.

Videotapes of shooting scenes provide a "real-life" view of the scene and are usually not subject to the hearsay objections that computerized animations often prompt. Videotaping of shooting scenes should be a standard practice and a supplement to still photography. Once again, the same rules that apply to general crime scene videotaping also apply to videotaping shooting scenes. These general rules are briefly reviewed in the following subsection.

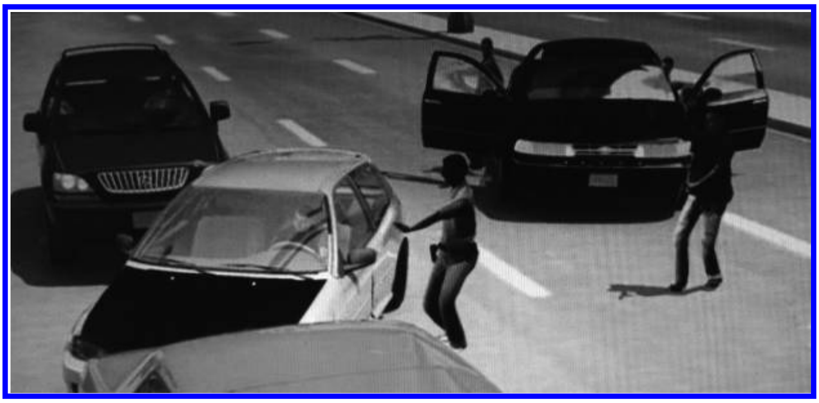


Figure 19.16 Animated view of witness through window screen.

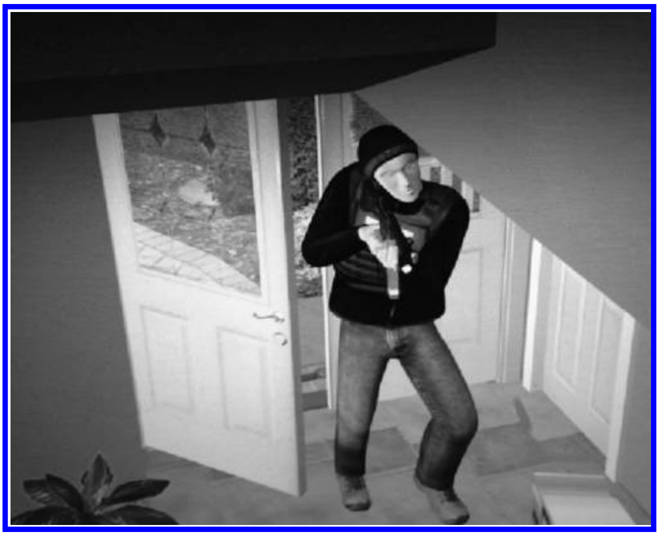


Figure 19.17 Animation of view from stairs of entry into residence.

General Videotaping Protocol for Shooting Scenes

- Begin with an oral introduction while focusing on a case identifying card that shows the date, location, case number, and photographer.
- Turn on the date and time functions and keep them on during the taping—this will allow the viewer to confirm when the taping is continuous and to identify starts and stops as well as confirm the time and date of the taping.
- The decision to narrate during the taping will largely depend on departmental procedures and preferences; one consideration is to narrate only for purposes of giving general orientation/location during the taping—many jurisdictions prefer not to have the audio on during taping to avoid the unwitting recording of background statements made by persons at the scene.
- Move the camera *slowly*, pausing for several seconds on items of evidentiary value—generally, when the video camera is panned across a scene, there is a tendency to move too quickly; the videographer must move the camera very slowly in order to be effective.
- Use the zoom judiciously and zoom in and out *slowly*—rapid zooming looks unprofessional and serves as a distraction.
- When moving from one area to another area to resume taping, using the fade feature on the camera allows the break in taping to take place smoothly.
- The ending of the tape should be stated on the audio and is shown by focusing on an “end of tape” card—this helps show that there are no missing segments at the end.

These steps help ensure that the videotape will be professional in appearance. The use of some or all of a shooting scene videotape in the courtroom can allow the jury to have a better understanding of the scene and the interrelationships of the physical evidence that still photographs simply cannot do. With regard to the decision of whether to have the audio on during taping and to narrate to one degree or another, this can be done and the audio can always be turned off during courtroom presentation if desired. With no narration whatsoever, it is sometimes confusing as to what the particular perspective was in a certain view or what the particular evidence item was. For example, a drop of blood on a parking lot can be very difficult to discern without the viewer knowing that is what the camera is focusing on.

Full-Scale Reproductions

From time to time it is useful to create a full-scale reproduction of a room or other part of a shooting scene and set it up in a courtroom for the jury. Photographs alone, including videotapes, frequently do not allow the viewer to appreciate the spatial relationships inside the scene. It is quite common, in the author's experience, to have viewed scene photographs and then visit a scene and realize how different the actual interrelationships of walls, doors, and other objects are than what the photographs depicted.

Full-scale reproductions for courtroom demonstration can range from 2-D floor plans that use strips of tape to represent walls to full 3-D versions. Obviously, there are limitations to what can be set up in a courtroom, both from an admissibility standpoint and a practical standpoint. These considerations not withstanding, courtroom reproductions can provide the jury with a perspective that could otherwise only be achieved by actually visiting the scene.

The use of scale models is an alternative to full-scale models with the obvious advantages of portability and ease of setup. The downside of scale models is their inability to allow jurors to visually "get inside the scene" in the same manner that full-scale models do.

The need for full-scale models as demonstrative exhibits in a shooting reconstruction presentation is clearly a decision that the prosecutor or defense attorney must make. However, it should be an option that the shooting reconstructionist considers and brings to the attention of the respective attorneys for their consideration. In the author's many years of shooting reconstruction experience and subsequent courtroom testimony, the need for full-scale models has, admittedly, been pretty limited. The few times that it has been used, however, it proved to be very effective.

In one case, it was important that the jury have a clear understanding of how confined a bedroom was in which a shooting took place. Cardboard pieces were used to represent the floor of the room and 3-inch wide strips of tape were used to create outlines of the bedroom furniture. This was laid out on the courtroom floor so that the jury could see just how confined the room was.

In another case, the actual chair that the victim was sitting in when he was shot was set up in the courtroom. Trajectory rods were inserted into the chair and somewhat of a reenactment was conducted to allow the jury to see how close the defendant was from the victim when the shots were fired. In this particular case, no walls or doors were a consideration.

As another alternative to setting up a full-scale reproduction in the courtroom, the full-scale reproduction can be set up elsewhere and a videotape made and played for the jury. One example of this involved a double homicide in which a young couple was found on the bedroom floor of their apartment lying side by side with their throats slit. Before trial, it was decided that it was important that the jury understand just how confined the crime scene was in support of the theory that the murders were carried out execution style. Rather than producing a full-scale reproduction of the scene, it was decided to use the actual apartment. However, a new resident was in the apartment, and none of the original furniture was present. Using the crime scene diagram, measurements for the furniture present at the time of the murders were obtained and used to create cardboard mockups.

The furniture present in the apartment had to be moved out, all with the gracious cooperation of the apartment resident, and the mockups put into place. A large pool of blood was simulated with a poster board cutout. Individuals of similar size and appearance were used in a reenactment that was videotaped from different perspectives. The videotape was then played for the jury.

PowerPoint Presentations

More and more PowerPoint presentations are making their way into the courtroom. PowerPoint presentations offer another way of presenting photographs and diagrams to the jury. Crime scene photographs can be interspersed with reenactment images and/or crime scene diagrams for added explanatory quality.

PowerPoint presentations allow the insertion of arrows, lines, circles, and other effects that can be used to highlight certain parts of images. Some examples are shown in Figures 19.18 and 19.19.

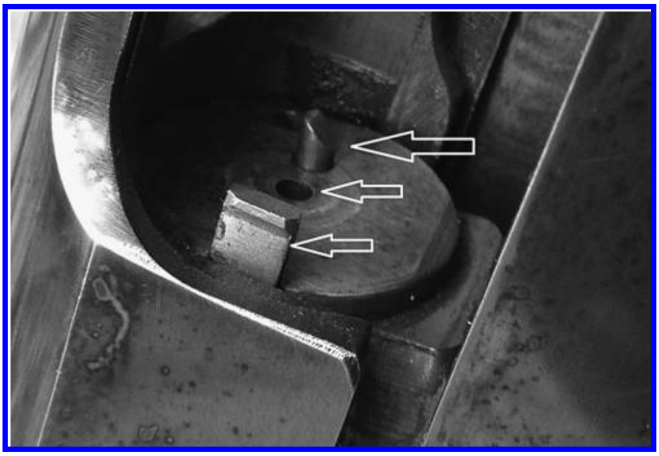


Figure 19.18 Court exhibit showing (top to bottom) ejector, firing pin aperture, and extractor.

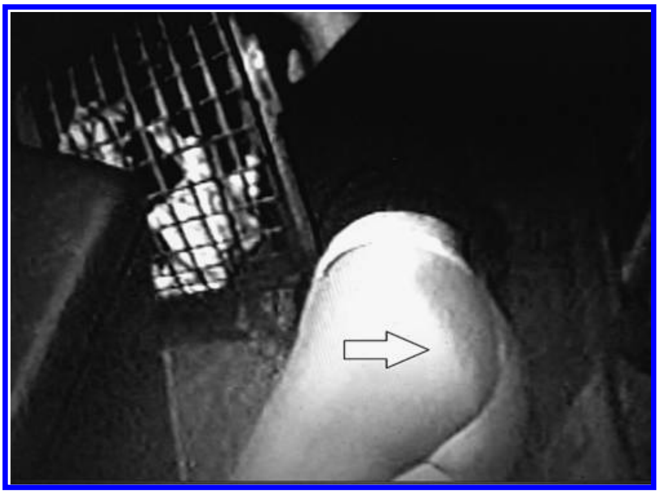


Figure 19.19 Postmortem lividity.

PowerPoint presentations for courtroom use should be prepared according to a protocol similar to that used for any visual presentation.

Considerations for Courtroom PowerPoint Presentations

- Begin with a simple title frame—such as “The Reconstruction of the Shooting of John Doe.”
- Use a title for each image that simply defines what is being represented—such as “northwest bedroom as viewed from the south door.”
- Avoid “glitz”—save animation, sounds, etc., for other presentation forums.
- Limit each slide to one major point and limit the total number of slides in the presentation to only those that are essential to presenting all of the major points—if the presentation becomes too lengthy, the jury can lose interest.
- Avoid the use of tables, charts, or diagrams that have excessive detail—if too much information is presented in a single slide, major points can become lost in the details.
- A summation slide (or slides) for the major points or conclusions is an effective way to conclude—as with any presentation, it is important to summarize the main points by way of the conclusion.

Photoshop in Reports and Court Testimony (Contributed by NYPD Detective Sergeant [ret.] John Paolucci)

Image editing software is a useful tool for experts to create demonstrative exhibits for insertion into reports or to present during courtroom testimony. When an image is referenced in a report, the expert has to be painstakingly precise in drawing the reader’s attention to the particular detail that the expert wishes to highlight, and risks having his words misinterpreted by the reader or manipulated by opposing counsel to have an entirely different meaning. When image editing software is used to create a demonstrative exhibit, the enhanced image can contain an enlargement of the detail in the photo that the expert wishes to highlight, and can also be accompanied by text that clearly delineates the significance of the detail.

Image editing software proved useful in the following case where the defendant claimed that the victim attacked him with a machete, inflicting an incised wound on his left forearm, and he was forced to shoot her in self-defense. The prosecution claimed that the defendant executed the victim and staged the scene by planting the machete because the cigarette pack in her hand proves that she never had the machete in her hand (Figure 19.20).

Upon closer examination of the cigarette pack one side had bloodstains with linear demarcations that suggest the presence of an object with a straight edge, curved at one end, had been in contact with the cigarette pack at the time the blood was deposited on the cigarette pack. The other side of the cigarette pack had a pattern of bloodstains consistent in size and distribution with high force impact spatter (Figure 19.21).

The victim was shot one time but the bullet created two distinct gunshot wounds. One wound was a graze to the base of the right thumb and the other was a gunshot wound at the base of her neck on the right side, which was determined at autopsy to be an entrance

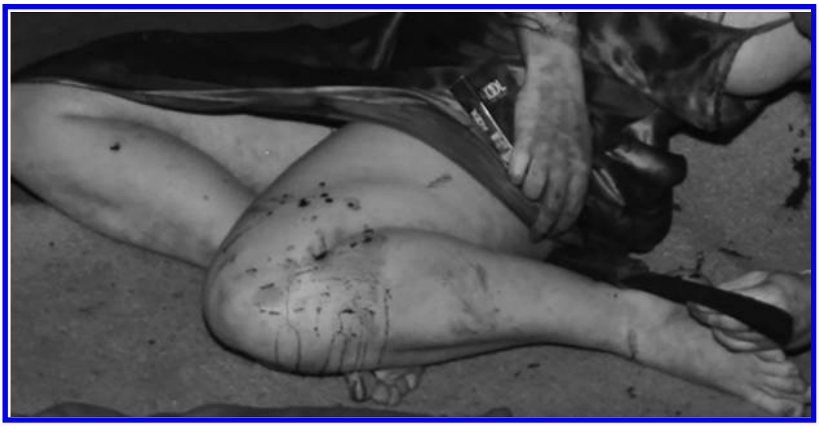
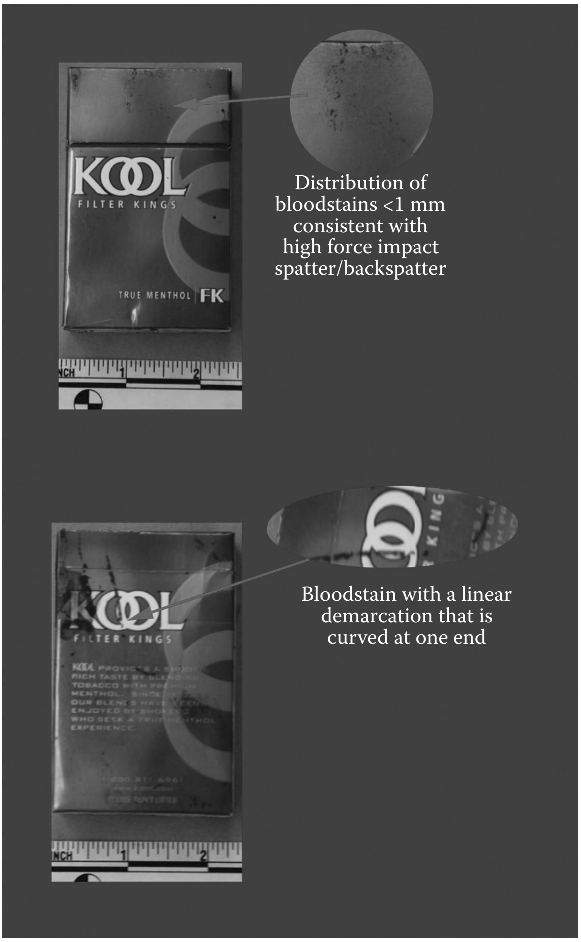


Figure 19.20 Cigarette pack visible in right hand.


KOOL
FILTER KINGS
TRUE MENTHOL FK
INCH 1 2

Distribution of bloodstains <1 mm consistent with high force impact spatter/backspatter

Bloodstain with a linear demarcation that is curved at one end

Figure 19.21 Bloodstains on cigarette pack.

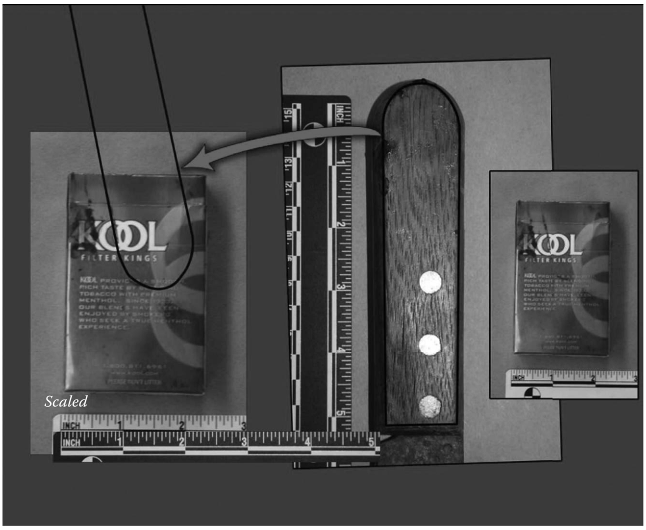


Figure 19.22 Overlay of knife handle.

wound. The locations of these wounds are consistent with the victim having her right arm in a "cocked" position, which the defendant claimed was an aggressive stance where she had the machete raised in preparation to strike him again. The prosecution claimed that it was a defensive posture and the victim was cowering with her arm raised as a reflexive response to having the muzzle of a firearm pointed at her. The high force impact spatter on the cigarette pack is consistent with the victim holding the cigarette pack in her hand in close proximity to the gunshot wound to allow backspatter from the bullet entrance wound to be deposited on the cigarette pack. The backspatter would support either side's contention as the defendant claimed that he had surprised the victim when he overheard her state that she was going to rob him, which would explain why she may have had both the cigarette pack and the machete in the same hand.

The bloodstains on the side of the cigarette pack opposite the side with the backspatter were suggestive of the machete so photo imaging software was needed to demonstrate how the machete handle would have made that transfer stain. First it is necessary to scale both images since scales were included in the evidence photos. Then the outline of the machete handle can be highlighted and dragged over to the photo of the cigarette pack to demonstrate that the machete handle is consistent with the linear bloodstain that has a curvature on one end. The blood source to create the backspatter was the bullet hole entrance to the neck while the blood source that created the bloodstains on the opposite side was the graze wound at the base of the thumb (Figure 19.22).

Court Testimony

As with any forensic investigation, it is one thing to carry out the appropriate examinations and formulate conclusions as to their meanings, and quite a different matter to be able to articulate them in written form. Providing oral testimony in a clear, concise, and understandable manner is still another challenge and, perhaps, the most difficult of all. Many very good forensic scientists and investigators have difficulty being effective witnesses under the stresses of courtroom testimony. However, this is truly where "the rubber meets the road." A very thorough and well executed shooting reconstruction can become diluted and made to appear insignificant by an inept courtroom presentation. A few reminders of the fundamentals of courtroom presentation are perhaps in order here.

Courtroom Presentation Basics

- Approach the witness stand in a confident manner.
- Speak clearly and confidently.
- Make eye contact with the jury while testifying.
- Avoid exhibiting any mannerisms or nervous habits.
- Answer questions in the same manner (same articulation and enunciation) for both the prosecution and the defense and with the same degree of courtesy and respect.
- Know your subject (avoid having to fumble through reports/notes excessively).
- Be prepared to defend your conclusions while acknowledging that other scenarios are also possible.

The last point mentioned in the list is worthy of some discussion. As has been emphasized throughout this text, shooting reconstruction is the development of a likely or probable scenario as opposed to the *only* scenario in most cases. The investigator who is presenting the reconstruction of a shooting in court must be prepared to acknowledge other *possible* scenarios while maintaining the focus on that which is deemed most *probable*. The decision as to whether or not to present the less likely alternative scenarios during direct examination along with the probable scenario is clearly one that the sponsoring attorney should make. Nonetheless, it is likely that questions pertaining to alternative explanations for the events of a shooting will arise during courtroom testimony, and the witness must be prepared to address these and explain why they are considered less likely.

The following section was contributed by the author's mentor and longtime friend, Max Courtney of the Mansfield, Texas, Police Department. Of particular note are the scale models that Max built himself (a truly lost art, but something a jury can "reach out and touch" as opposed to electronic animations).

Trial Presentation and Demonstrative Evidence

The shooting reconstruction expert has two considerations in trial preparation: first, the reconstruction, itself, and second, reducing the findings to a presentation that will be understandable and believable to the trier of fact. The tasks are different—the former is a scientific endeavor; the latter is, although built on a scientific foundation, more of a creative activity. Studies show that most people today are visually oriented—that is, they need to see something to fully understand a concept. Importantly, even the best shooting reconstruction has little worth if the triers of fact do not understand the details.

The methods of presentation in court are countless. Each witness (and each attorney who sponsors the expert) will have methods that are comfortable and practical. The time element will dictate in many cases just how in-depth the presentation will go; and, of course, the complexity and the gravity of the case will help to determine the extent to which the expert will go. In some cases, the witness might prepare the trial exhibits. In others, the attorney, with the help of the witness, might arrange for someone else (e.g., a graphic artist) to do the actual preparation or assembly of the exhibits.

Different Types of Evidence

Cases vary widely, as do the needs for special trial exhibits that the witness will use to explain the findings to the judge or jury. *Physical evidence* usually consists of items found at a crime scene or perhaps on a suspect. They include firearms, tool marks, fingerprints, hairs, fibers, footwear impressions, and numerous other types of evidence. To admit physical evidence, the attorney usually must prove up a chain of custody to ensure that no tampering has occurred. *Demonstrative evidence* consists of photographs, graphs, tables, diagrams, recordings, models, computer simulations, and—yes—demonstrations that aim to clarify the testimony of the witnesses. Often, these exhibits are not supposed to consist of real evidence but are used to help the fact triers understand and remember the real evidence. They must, however, “fairly and accurately” portray the real object or the concept that they purport to demonstrate.

Kinds of Demonstrative Evidence

This includes several types of explanatory evidence to show the jurors what the witness saw and heard, or how the examiner’s findings were determined. The most common form is a *photograph*. Items at a crime scene are captured as images so that the jury can see what the witness saw, to the extent that is possible. A photograph of a bullet hole in a wall or in a body will allow the jurors to see the hole in its context. Figure 19.23 shows a shored exit hole that is part of a bullet wound. This allows the jury to observe the physical characteristics of the wound that allow the pathologist to determine that the exit was shored. This, in turn, leads to a finding that the body was pressed against a firm surface when the bullet exited the body (in this case, a mattress). This fact would be useful in reconstructing the shooting by placing the victim in a supine position when the shot was fired. Sometimes, an artistic rendering might accomplish the same objective.

Figure 19.24 shows injuries to a woman’s abdomen resulting from a self-inflicted gunshot, which she originally blamed on another party. The combined tissue injuries show evidence that the revolver was lying against the skin when the shot was fired.

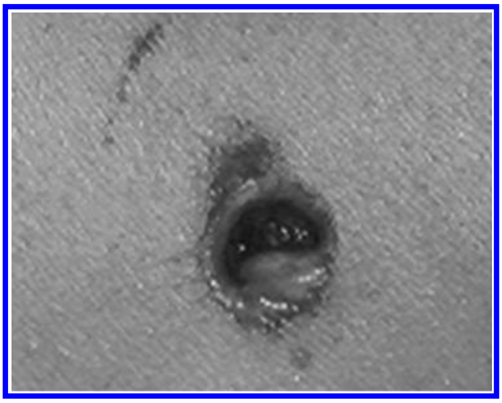


Figure 19.23 Shored exit hole.

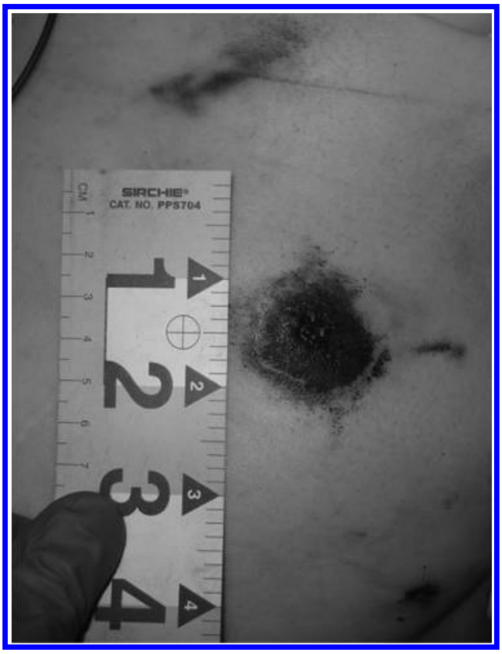

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Figure 19.24 Abdominal trauma.

Another commonly used example of demonstrative evidence is the *scene diagram*. A diagram allows the jurors to view the scene in a particular context, such as a bird's eye view (from above the scene). The diagram is generally prepared from a sketch made contemporaneously with the scene investigation. Some are drawn "free-hand" (Figure 19.25). Others are prepared using computer-aided design (CAD) software (Figures 19.26 and 19.27).

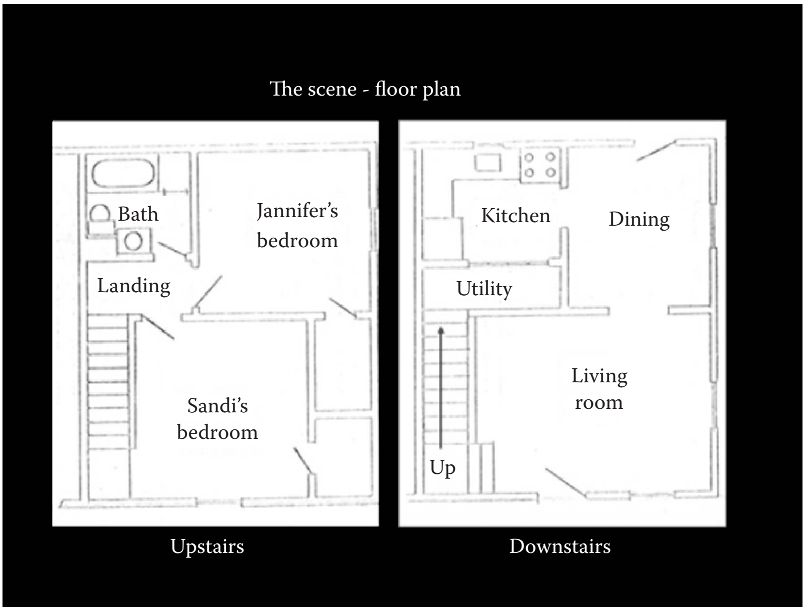

The scene - floor plan
Bath
Jannifer's bedroom
Landing
Sandi's bedroom
Upstairs
Kitchen
Dining
Utility
Living room
Up
Downstairs

Figure 19.25 Scene diagrams.

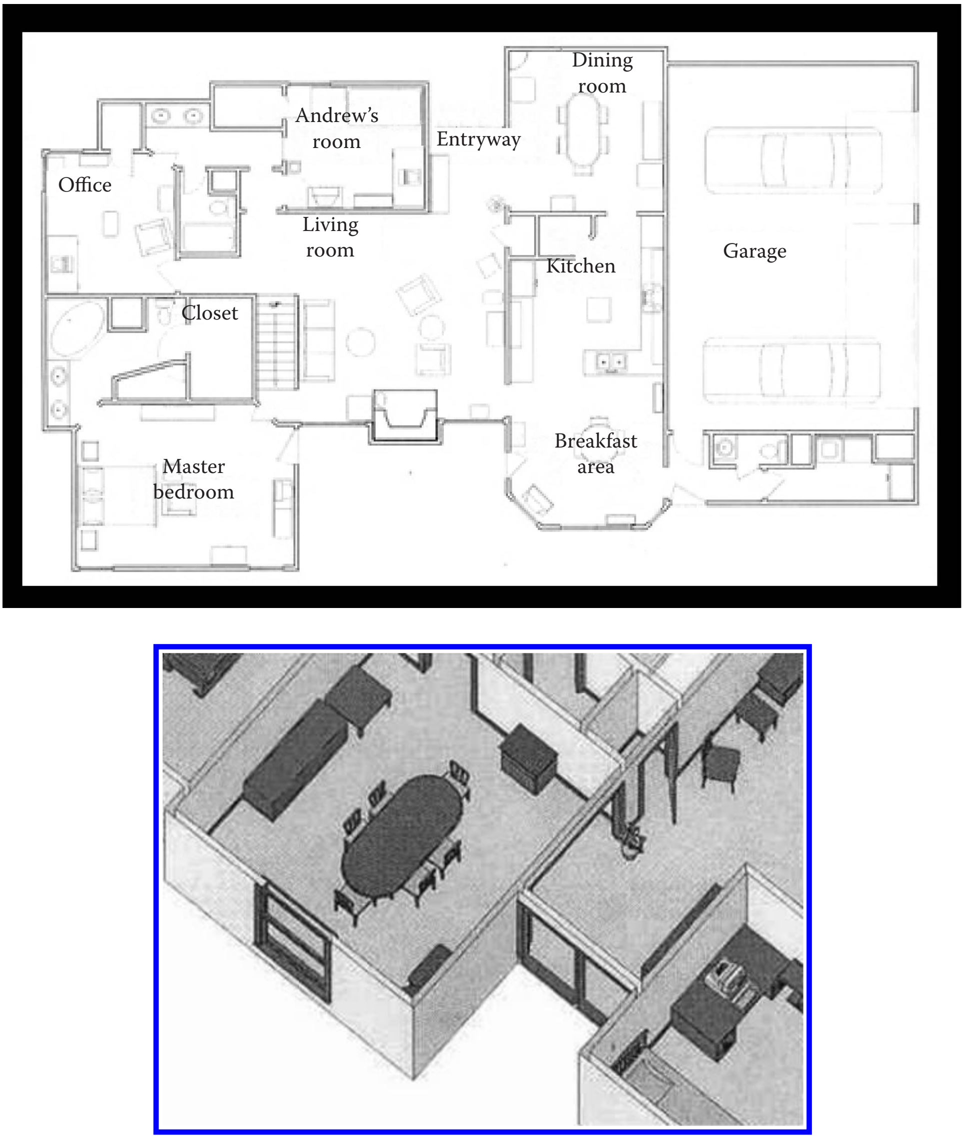

Dining room
Andrew's room
Entryway
Office
Living room
Kitchen
Garage
Closet
Breakfast area
Master bedroom

Figure 19.26 Computer assisted diagrams (CAD).

Furthermore, Figure 19.27 shows enhancements of the CAD diagram when merged with another software—in this case, Microsoft Office PowerPoint.

Other types of diagrams include those of cars or cars in a scene context (Figures 19.28 and 19.29). Still other types are body models, which are used to depict injuries to the body and bullet trajectories (Figures 19.30 and 19.31). For those who have little artistic skill, graphic arts, clip art, and other images are useful. Also, many police agencies have equipment and trained personnel to do total data station mapping with a theodolite. Although these are more often used in traffic crash scenes, they are still useful in shooting scenes, particularly for outdoor locations.

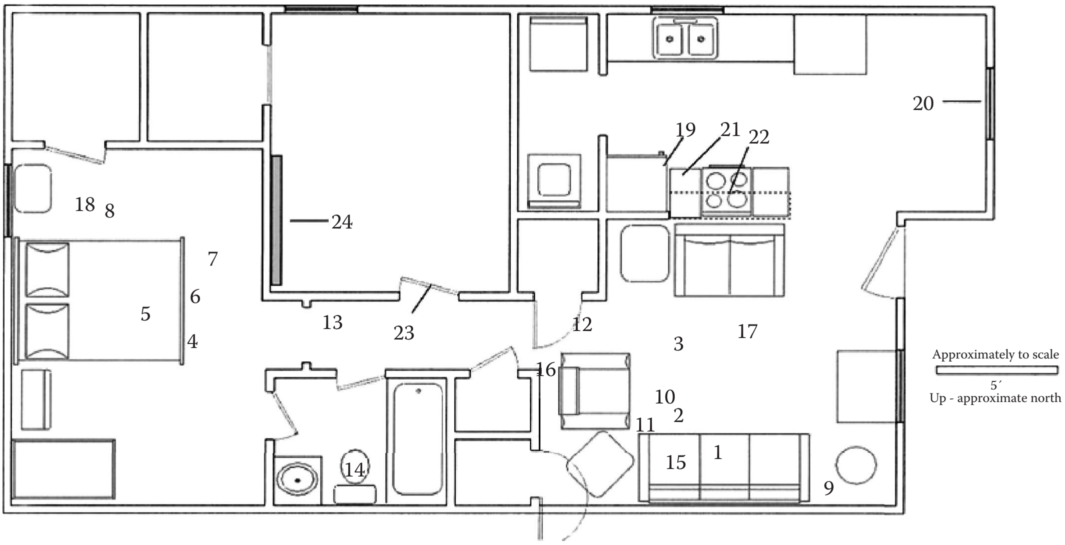
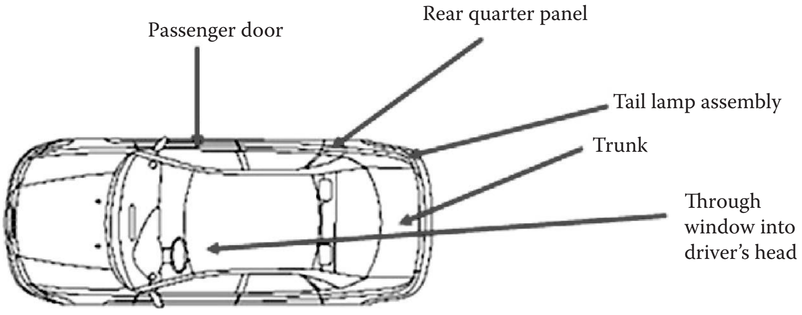

20
19
21
22
18
8
24
7
6
5
4
13
23
12
3
17
16
10
2
11
15
1
9
14
Approximately to scale
5′
Up - approximate north

Figure 19.27 CAD diagram of scene.


Passenger door
Rear quarter panel
Tail lamp assembly
Trunk
Through window into driver's head

Approximate shot trajectories

Figure 19.28 Approximate shot trajectories.

Charts and graphs are sometimes useful to show data. The instances where these could be used are limitless. Figure 19.32 shows an audio wave form of the sounds of two gunshots. This graph could be used to demonstrate elapsed time between shots in a situation wherein the gunshots were recorded, perhaps via a recorded telephone line. Of course, audio recordings might prove useful in some cases.

Maps are useful in showing larger areas. Google Maps, Google Earth, and Pictometry are useful in showing aerial views of outdoor scenes. Numerous online sources, including the U.S. Geological Survey, exist for maps of essentially any area. One problem with picture maps, including Google Earth and Pictometry, is that the views generally are not contemporaneous with the incident under investigation. This can change the locations of cars, foliage, and even added structures. Figure 19.33 shows a Pictometry view of a shooting scene wherein numerous shots were fired. The view is overlaid with a printout from a

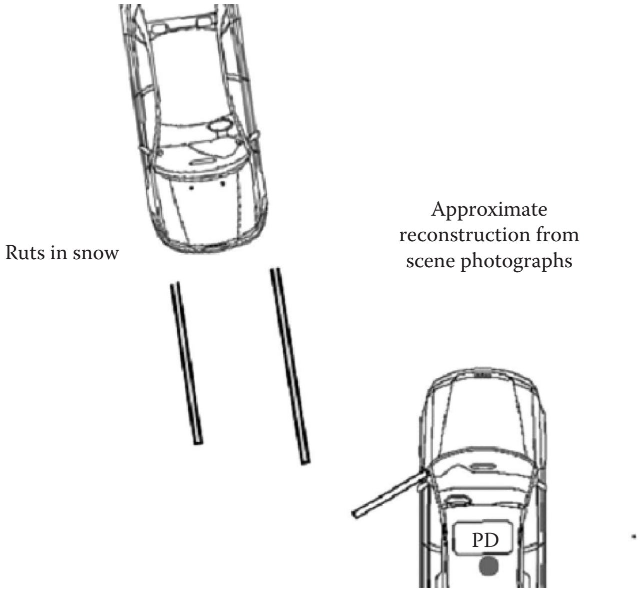


Figure 19.29 Approximate reconstruction from scene photographs.

total data station to add some objects not depicted in the Pictometry view. Afterward, the trajectories of the bullets were digitally added.

Mockups are reconstructions of objects for display in court or indirect display through photographs or video clips. These might include a wall, a room of furniture, or even a motor vehicle. They might be the actual objects themselves, which are reassembled in the courtroom or might be made from similar materials. Figure 19.34 (a) shows a room with a broken door window; a question arose as to whether the door was open or closed when the window was broken. To test the hypothesis, a mockup (b) was prepared.

In particularly complex cases, the expert might construct a *scale model* of the scene. This is useful in cases where the involved parties move through a scene, when numerous shots are fired, or when the jury might not easily grasp the significance of distances or sight lines. Figure 19.35 shows a scale model of a 102-unit apartment complex, the scene of a shooting that progressed through the complex into several apartments. The top photograph shows the model during its construction, whereas the bottom image shows one of the many facets of the completed project. In another case (Figure 19.36), a scale model of a mobile home was prepared to illustrate the complexity of the reconstruction of the police-involved shooting that featured dozens of shots fired by multiple parties in different locations. Each trajectory was approximated with a wooden dowel; the dowels were color-coded to show which weapon fired a particular shot.

On some occasions, it might be useful to combine several techniques. For example, scale models of homes have been enhanced with matching-scale photographs of bloodstains and other objects. The photographs were then glued to the walls or floors. In another case, rods depicting bullet trajectories were punched into a model head. The model head was then superimposed over a photograph of the victim at the scene in the body's resting place. The resulting image demonstrated that the shots could not have been fired while the body was in this position (Figure 19.37).

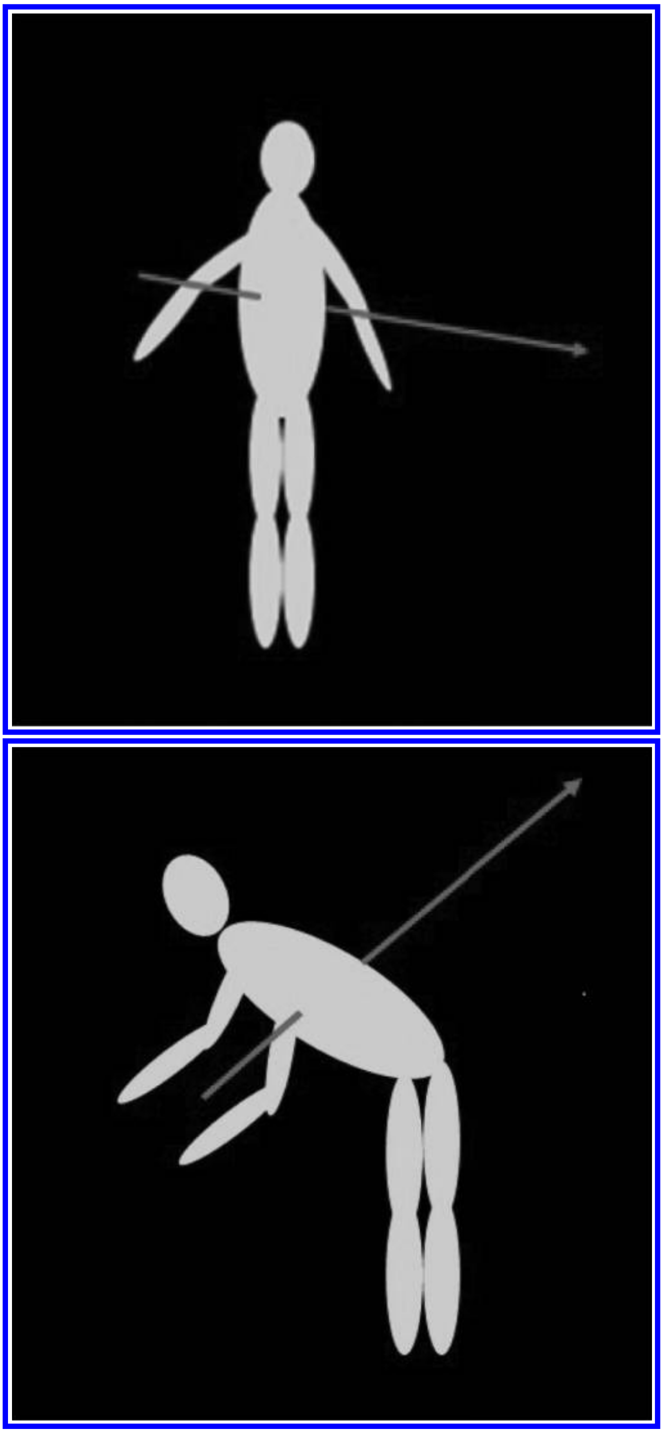


Figure 19.30 Body models illustrating trajectories.

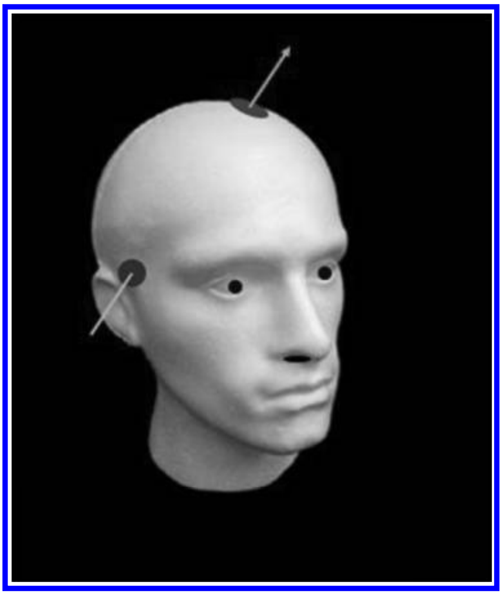


Figure 19.31 Head model illustrating trajectory.

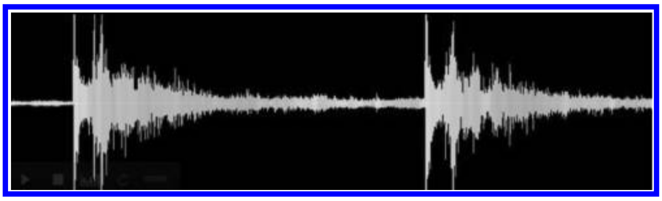


Figure 19.32 Gunshot sound wave pattern.

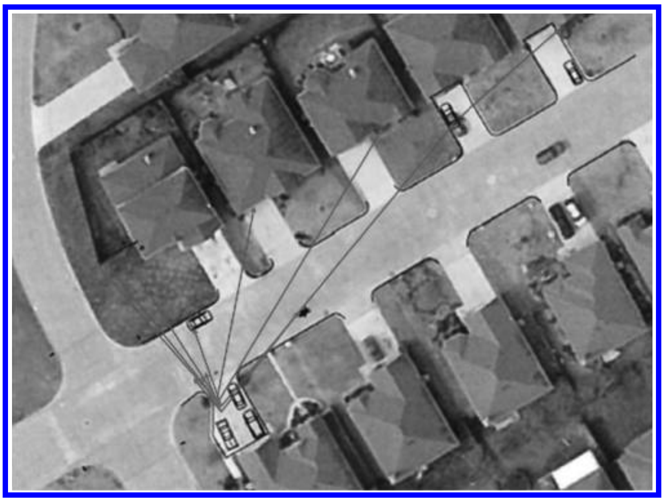


Figure 19.33 Satellite view using Pictometry©.

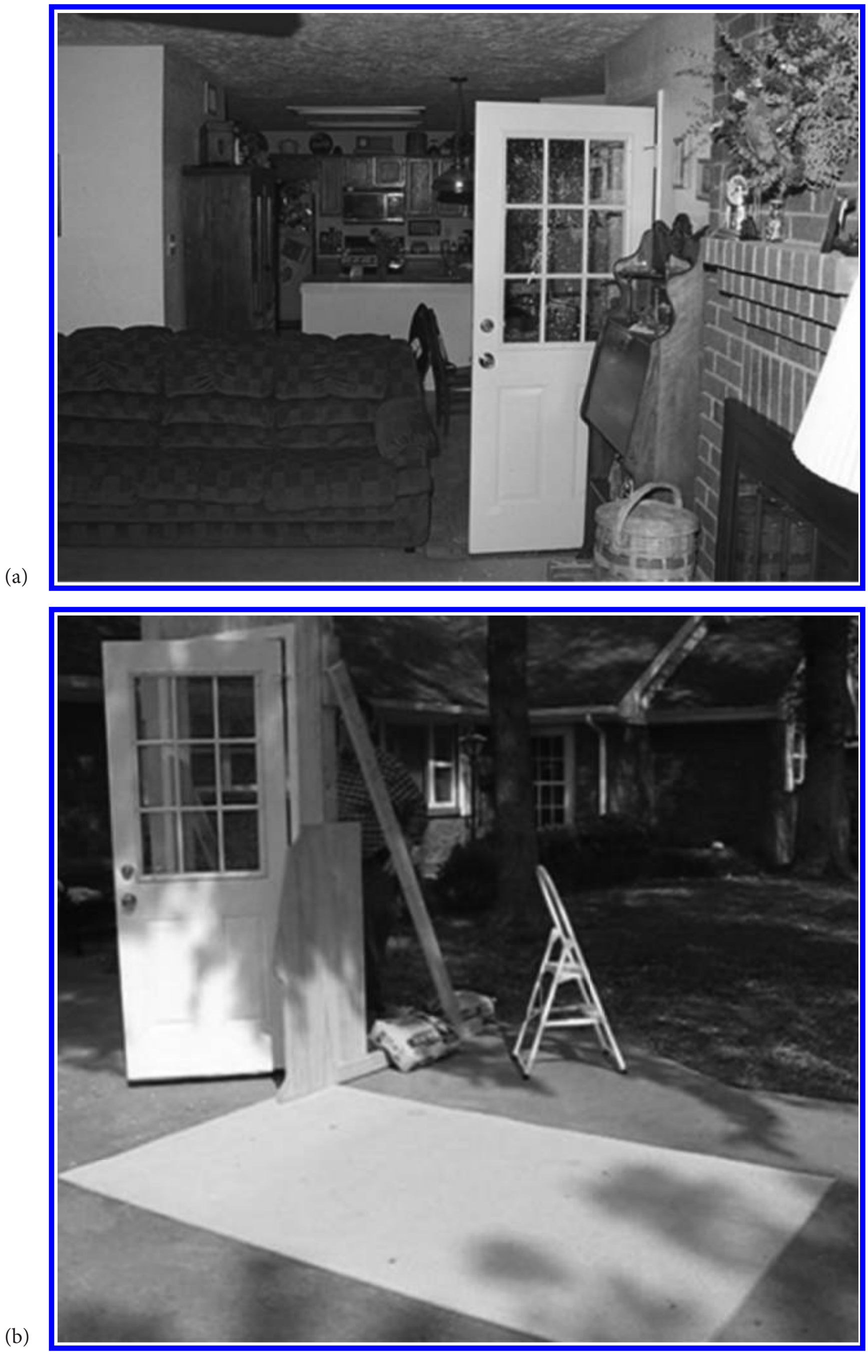


Figure 19.34 Crime scene (a) and mock-up (b).

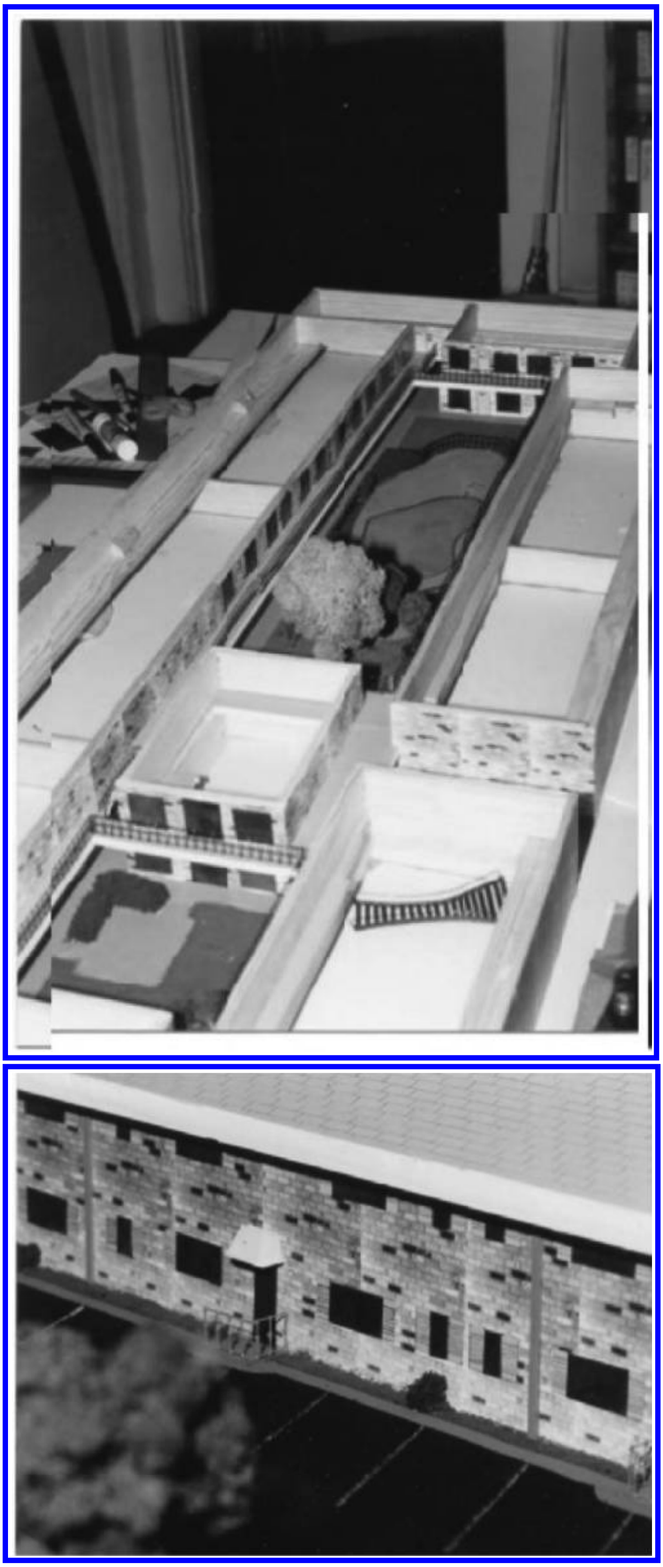


Figure 19.35 Scale models.

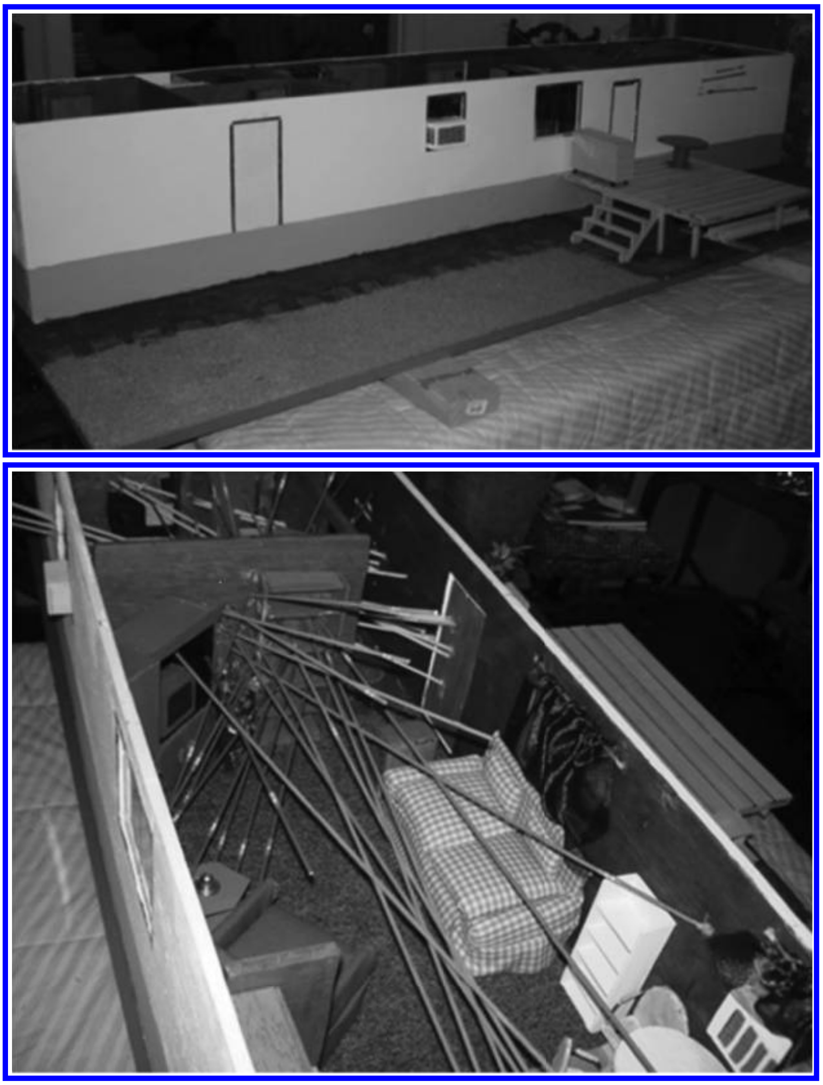


Figure 19.36 Scale model with bullet trajectories.

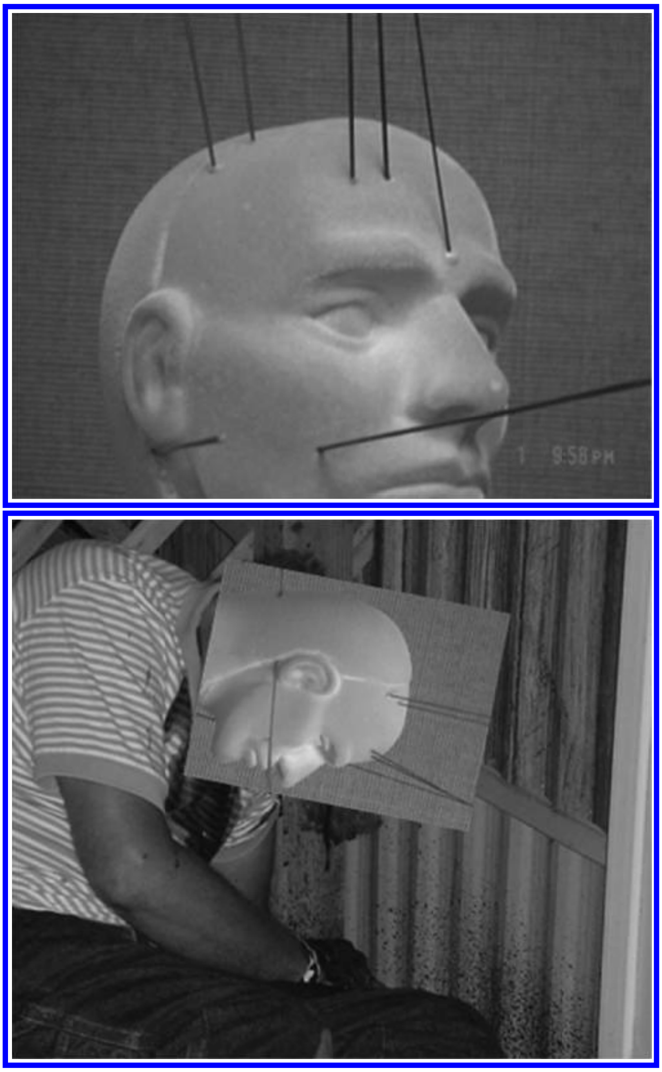


Figure 19.37 Overlay of trajectory mannequin.

Suggested Readings

Dillon, J.H., Graphical Analysis of the Shotgun/Shotshell Performance Envelope in Distance Determination Cases, *AFTE Journal*, Vol. 21, No. 4, Oct. 1989, p. 593.

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Maximizing Crime Laboratory Results

20

Today's modern crime laboratory is capable of obtaining unprecedented analytical results. The combination of highly trained forensic scientists and sophisticated instrumentation specifically designed for forensic purposes is an unbeatable combination. Gone are the days when instrumentation designed for some other purpose (e.g., industrial applications) had to be modified for forensic analyses as illustrated in Figures 20.1–20.6.

There is, however, one aspect of the forensic laboratory/criminal investigative link that frequently results in less-than-appropriate analyses/findings. The "disconnect" comes when the submitting agency fails to request the appropriate analyses, fails to appraise the laboratory of pertinent case details, or fails to collect adequate specimens for testing and/or control samples.

Failure to Request Appropriate Analyses

Most crime laboratories are not looking for something to do—they have plenty of work and are typically dealing with backlogs of work. Thus, "If you don't ask, you don't get." In a perfect world the forensic scientist, upon reviewing a case submission and the request for analysis, recognizes that there are additional tests that could be carried out but were not asked for. The analyst then contacts the lead investigator in the case and suggests the additional testing. Actually, that can and does happen, but it is typically something that is more common to a smaller agency with an in-house laboratory. A large state or federal laboratory seldom has the ability to carry out that sort of direct communication.

Most state and federal crime laboratories have manuals that they have created to assist user agencies in the proper collection and handling of physical evidence, but they do not always provide insight in what capabilities the laboratory might have for various types of evidence. Thus, it is up to the submitting agency to understand both the capabilities and limitations of the crime laboratory they are dealing with.

One way of handling that is through training. Unfortunately, most police training academies typically can only devote a few hours to the subject and depend on other means to educate their investigative personnel (e.g., in-service training classes) as to the specifics of forensic capabilities and limitations. When classes are taught by qualified instructors, this is a good way to get the information across.

Case Example

A police department is investigating a shooting incident in which the shooter claimed that he had a rifle out and was examining it when he "fumbled" it, and unintentional discharge occurred resulting in the bullet striking his girlfriend. A dark deposit was noted near the entry wound on the girl's chest by the emergency room physician, who

Figure 20.1 Forensic chemist.

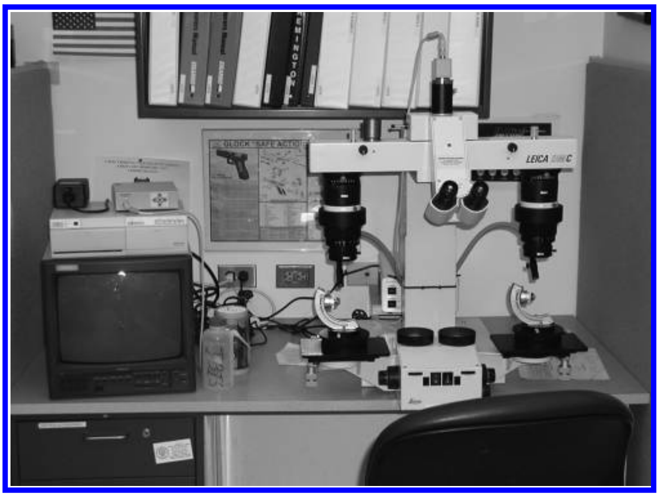

Figure 20.2 Firearm workstation.

categorized it as "gunshot residue from the rifle barrel being in contact (i.e., lying against) with the chest."

The rifle was submitted to a state crime laboratory with the request "examine for biologicals." There was no explanatory information given regarding the specific need to check the muzzle area for DNA from the victim. The crime laboratory report, when completed, reflected testing of the stock and trigger areas of the rifle only. Without a specific request and/or explanatory information, the crime laboratory had no way of knowing that the real area of interest was the muzzle area of the barrel.

Figure 20.3 Criminalist using a gas chromatograph–mass spectrometer (GC-MS).

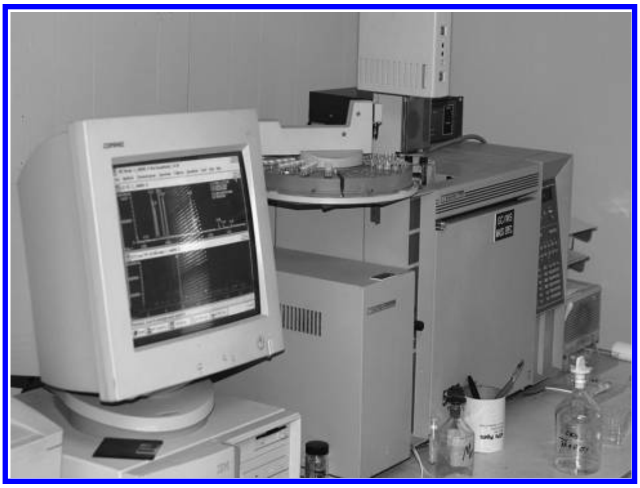

Figure 20.4 Laboratory instrumentation.

Figure 20.5 Laboratory analysis.

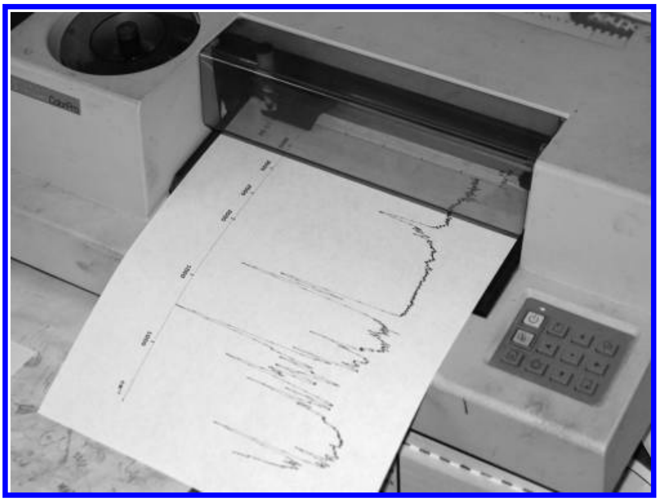

Figure 20.6 Infrared spectroscopy scan.

Failure to Provide Pertinent Details

Most evidence submission forms provided by crime laboratories have only very limited space for case detail information. This is primarily by laboratory design in an effort to avoid a long oration that fails to keep the focus on the forensic specifics. Accordingly, agencies often feel that they are required to "keep within the lines."

Whenever there is information that could be critical to explaining the potential findings in forensic analyses, the crime laboratory needs to be advised. If there is insufficient space provided on the evidence submission form, attaching a supplemental sheet that succinctly and clearly outlines the areas of interest/concern is appropriate.

Case Example

An officer-involved shooting incident under investigation was determined to have been the result of a single shot that first passed through the left hand of the suspect and then entered the right chest of the suspect. The officer stated the suspect had been within arm's length when he shot the suspect. The suspect claimed the officer had shot him while standing approximately 15 feet away from him.

Because the officer was not charged criminally, no examination/testing of the suspect's clothing was conducted by the agency's crime laboratory. Ultimately, the suspect (who survived) filed a civil suit against the agency and testing of the suspect's clothing was carried out by an independent laboratory. No information was provided to the laboratory as to the suspect's hand having been in the path of the bullet and associated residue and the probable disruption of gunpowder particles.

The laboratory report reflected that no recognizable powder pattern was found. Thus, the best the laboratory could do under the circumstances was to state that the shot took place "within the maximum distance" that powder particles would travel for the incident gun and ammunition. The maximum distance was determined to be 48–60 inches.

Although the reported distance was certainly inconsistent with the 15 feet alleged by the plaintiff, it was not “within arm’s length” either.

Failure to Collect Appropriate Samples/Controls

Many times at a crime scene, potential evidence is observed with no apparent source (i.e., “foreign specimens”). Clearly, these circumstances limit the ability of the scene investigator to collect control samples for comparison to the evidentiary material. Conversely, when there is a source (or sources) of materials that suggest a likelihood of transfer to an as-yet-undetermined suspect, it is incumbent on the scene investigator to take control samples for possible future laboratory comparison. Admittedly, one has to be selective in that endeavor.

The guiding principle for collecting apparent “foreign” materials at a scene is to collect it rather than risk leaving valuable evidence behind. That requires added time in documentation, packaging, and submission, but it is the best policy. With respect to deciding what should be collected in the way of control samples in “no suspect” cases, practicality combined with good logic should guide the investigator. Obviously experience is a good thing to base selectivity on, because “you can’t take it all.”

Case Example

The female victim of a homicide, the night clerk at a hotel, was found lying in a pool of blood in the breakfast area adjacent to the hotel lobby. Her throat had been cut and her ankles appeared to have ligature marks. A small piece of white cord was lying on the floor nearby. No source for the cord was found in the immediate area. Because of the ligature marks and the lack of any similar cord, officers were sent out to scour the hotel for any similar cord.

The guests had been ordered out of their rooms and were assembled out in front of the hotel in the parking lot. Ultimately, one of the officers sent out to search for a source of the cord returned with a piece about 3 feet long that he had taken from one of the guests who had been using it as a leash for his dog.

A search warrant was obtained for his room, and bloody clothing and a piece of cord similar to that found near the body were found. A search warrant was then obtained for the man’s residence, and a spool of the cord was located in the garage.

This case illustrates what may be required to obtain necessary control samples. Although it does not always work out as well as it did in this example, if no effort is made the end result is quite predictable.

Case Example

Two youths allegedly took a third youth out to a rural area and into a field where they both purportedly shot him to death. The scene investigator had heard that cartridge case locations are unreliable indicators of shooter location under any circumstance. Accordingly, he merely collected the fired cartridge cases without documenting their locations. Later, it was determined that only 9-mm fired cartridge cases were involved. Had their locations been properly documented, the relative positions of the two shooters could likely have been determined, as well as any movement within the scene, allowing the firearm examiner to identify which gun fired which cartridge case.

Summary

The crime laboratory refers to a familiar saying that pretty much covers most of the issues discussed here:

> Garbage in equals garbage out

Investigators must understand both the capabilities and the limitations of the crime laboratory very clearly in order to properly document, preserve, and collect evidence at crime scenes. They must provide pertinent case facts and make specific requests for analyses in order to maximize the possible results of forensic analyses. It is the scene investigators' responsibility to maintain a "reconstruction mentality" that guides them in making the appropriate requests to the laboratory.

Suggested Readings

Mozayani, A. and Noziglia, C. (editors), *The Forensic Laboratory Handbook Procedures and Practice,* 2nd ed., Humana Press, New York, 2012.

Siegel, J.A. and Houck, M.M., *Fundamentals of Forensic Science,* Elsevier Academic Press, San Diego, 2006.

Glossary

AFTE: Association of Firearm and Tool Mark Examiners
Angle gauge: Device used to measure vertical angles
Angle of deflection: Angle between the preimpact path and the postimpact path
Angle of impact: Interior (acute) angle of the axis of an impinging bullet with a target
Angle of ricochet: Angle of departure of a bullet or shot pellet from a substrate
Annular rim: Outer circumference of the cartridge case base (location of priming mixture in rimfire cartridges)
Annulus: Circular area between the primer and the primer pocket
Antimony sulfide: Component of most priming mixtures that acts as a fuel
Anvil: Internal metal component in a boxer or Berdan primed cartridge case (or the breech end of the chamber in a rimfire firearm)
Anvil mark: Microscopic mark impressed on the forward face of the rim of a rimfire cartridge case during firing
BB: Steel or lead air rifle shot (0.175 inch in diameter)
Back spatter: Blood droplets directed back toward the force that produced the spatter (often associated with gunshot entrance wounds)
Ball powder: Gunpowder with a spherical shape (originally developed by Olin Co. in the 1930s)
Ballistics: Study of projectile motion, often confused with firearm identification
Barium nitrate: Component of most priming mixtures that acts as an oxidizer
Battery: Ready-to-fire condition of a firearm (as opposed to "out of battery"—will not fire in that condition)
Bearing surface: Surface of a bullet that is in direct contact with the inside surface of a gun barrel during firing
Bird shot: General term for any shot smaller than buckshot
Black powder: Physical mixture (as opposed to a chemical mixture, which is inseparable) of charcoal, potassium nitrate, and sulfur used in antique and replica firearms
Blowback operation: Firearm action (semiautomatic) that uses the pressure from discharge to recycle the action to reload (slide is not locked to the barrel or frame)
Bolt action: Firearm in which the breech is always in line with the bore and manually reciprocates to load, unload, and cock (there are two principal types: rotating and straight pull)
Bore: Interior of a barrel forward of the chamber
Breech face: Part of the breech block or bolt that is against the base of the cartridge case or shot shell during firing
Broach: Rifling cutter that cuts all the grooves simultaneously
Buckshot: Lead pellets ranging in diameter from 0.20 to 0.36 inch and normally fired in shotguns
Bullet: Projectile portion of a cartridge
Bullet jacket: Metallic covering over bullet core

Bullet wipe: Combination of grease and soot debris around the margins of a bullet entry from the passage of the bullet

Caliber: Cross-sectional diameter of the barrel from land to land (i.e., the minimum bore cross-sectional diameter), which is also the cross-sectional diameter of a bullet (in millimeter or inches)

Calipers: Device consisting of two moveable jaws or legs used to measure distance, thickness, or width

Cartridge: Ammunition component consisting of a cartridge case, bullet, powder charge (propellant), and primer

Cartridge case: Container for all the other components of a cartridge

Cartridge designation: Specific cartridge such as 7 mm Remington magnum (as opposed to caliber 7 mm)

Center fire: Cartridge with the primer in the center of the base (head)

Chamber: Rear part of the barrel bore that has been machined for a specific cartridge (revolver cylinders are multichambered)

Chamber marks: Individual characteristics imparted to the chamber walls during machining

Choke: Constriction in the muzzle end of a shotgun barrel (i.e., full, improved–modified, improved cylinder, skeet) or lack thereof (cylinder bore)

Class characteristics: Characteristics exhibited by an entire class or group

Clip: Separate device for magazine reloading

Cock: To place a firing mechanism under spring tension

Concentric fracture: Circular fracture of glass surrounding the point of impact

Conchoidal fracture: Fracture lines visible on the edges of broken glass that allow direction of force determination

Contact shot: Shot fired with the muzzle of the gun in direct contact with the substrate

Core: Portion of a bullet beneath the jacket

Critical angle: Angle at or below which a ricochet would be predicted

Cylinder gap deposit: Soot deposit resulting from gases escaping from the gap between the face of a revolver cylinder and the back of the barrel

Cylinder halo: Soot deposit on the face of a revolver cylinder around the margins of the chambers

Disconnector: Device intended to disconnect the sear from the trigger to prevent firing without pulling the trigger

Disk powder: Extruded form of gunpowder that is cut into small disks

Distance shot: Shot fired from a distance beyond which gunpowder particles can travel for a particular firearm and ammunition combination

Double action: Single pull of the trigger cocks and releases the hammer

Double base powder: Gunpowder consisting of nitrocellulose in combination with nitroglycerin

Ejection: Expulsion of a fired cartridge case or shot shell

Ejection (anomalous): Ejected cartridge case that follows a path contrary to that typical for that firearm/ammunition combination (an unexpected ejection path)

Ejection pattern: Particular pattern that ejected cartridge cases produce upon firing a weapon from a given position

Ejection port: Port from which fired cartridge cases are ejected

Ejector marks: Marks left on the base (head) of a cartridge case or shot shell by the ejector during the process of ejection

Exterior ballistics: Study of projectile motion upon exiting the muzzle of a gun barrel

Falling block: Single shot lever action mechanism in which the breech block slides vertically or nearly vertically down as the lever is worked

Filler wad: Cylindrical disk used to adjust shot shell volume

Firing pin: Part of a firearm mechanism that strikes the primer and initiates ignition

Firing pin impression: Impression left by the firing pin upon impact with the primer

Flash suppressor: Device affixed to the muzzle of a gun barrel to limit muzzle flash upon discharge

Flattened ball powder: Gunpowder produced by compressing ball powder

Forcing cone: Area just ahead of the chamber designed to align a bullet or shot charge with the bore

Frangible: Breaking apart upon impact (rather than bending or stretching)

Fully automatic: Weapon action that, once cocked, continues to fire until the ammunition supply is exhausted if the trigger is pulled and held back

Function testing: Examination of a firearm for operability and firing capability

Gas operated: Firearm system that uses gas from discharge to recycle the action

Gauge: Number of lead shot of a particular diameter to the pound (i.e., 12-gauge means 12 lead shot of the bore diameter to a pound, 16-gauge means 16 shot to the pound and so on)

General rifling characteristics (GRCs): Number, width, and direction of twist of rifling grooves

Griess test: Chemical test for nitrites used to detect gunpowder residue around bullet holes

Grooves: Helical grooves in the interior of the barrel to impart spin on the bullet

Gunshot residue (GSR): Gunpowder and primer residue resulting from discharge

Hammer: Part of the firing pin that imparts energy to the firing pin

Hammer forging: Process of forming the interior/exterior of a barrel by hammering

Handgun: Firearm designed to be handheld

High-velocity impact spatter (HVIS): Blood spatter produced by bullet impact and/or muzzle blast

Improved Military Rifle (IMR) powder: Tubular powder developed by Dupont

Individual characteristics: Accidental, random marks used to identify tool marks

Instantaneous incapacitation: Result of a bullet impacting the brain stem or spinal cord

Interior ballistics: Study of bullet behavior within the confines of the barrel

Intermediate range shot: Shot fired at a muzzle to substrate distance sufficient to produce powder stippling (skin) or deposition (inanimate objects)

Knockdown power: Erroneous and outdated term having no meaning for modern firearms/ammunition

Laminated glass: Two sheets of glass with a piece of plastic sandwiched in between—found in windshields of all modern U.S.-made vehicles

Lands: Raised areas between grooves in rifled barrels

Laser protractor: Protractor with a movable laser pointer that can be set to any angle ranging from 0° to 180°

Lateral angle of deflection: Right or left deflection of a bullet from its original line of travel as a result of ricochet (typically controlled by direction of bullet spin—right or left)

Lead azide: Chemical compound used in most priming mixtures
Lead splash: Result of bullet impact that vaporizes exposed lead followed by condensation
Lead styphnate: Shock-sensitive explosive found in priming mixtures
Lever action: Type of firearms action that utilizes a lever to move the breech mechanism
Line of departure: Straight line through the center of the bore out to infinity
Line of sight: Line from the sights to the target
Long gun: Firearm designed to be fired from the shoulder
Magazine: Integral or detachable device used to contain and feed cartridges into the action of a weapon
Magazine follower: Spring operated device that pushes cartridges up to a feeding position in a magazine
Magazine safety: Device that prevents firing without the presence of a magazine (e.g., Browning Hi-Power)
Micrometer: Precision measuring device used to measure small distances/thicknesses
Muzzle blast: Rapid expansion of gases resulting from the combustion of gunpowder in the discharge of a firearm
Muzzle imprint: Abrasion of the skin having the general shape of the muzzle of a gun as result of the muzzle blast in a contact or near contact shot forcing the skin back against the muzzle
Muzzle velocity: Bullet velocity upon exiting the barrel
National Integrated Bullet Identification Network (NIBIN): System for electronic comparison of bullets and cartridge cases entered into databases across the country
Near contact shot: Shot fired with the muzzle of the gun in close proximity to the substrate but not touching it
Nitrocellulose powder: Smokeless propellant whose principal ingredient is nitrocellulose
Nitroglycerin: High explosive and component of double-based gunpowder
Obturation: Sealing of the bore due to bullet expansion as a result of discharge pressure
Out of battery discharge: Discharge that results without the locking mechanism being closed
Pellet: Common term for small, spherical shot used in shot shells
Plumb bob: Metal object that is cone-shaped the point of which is oriented to the ground and the other end affixed to a line so that a perpendicular to the earth may be established
Polygonal rifling: Rifling with rounded edges instead of the usual square edges (hammer forged rather than cut)
Powder stippling: Result of powder particles striking the skin and abrading it and/or imbedding into the skin (powder tattooing)
Primer: Shock-sensitive explosive mixture that initiates burning of the propellant
Primer residue: Compounds of barium, antimony, and lead (unless lead-free primer)
Propellant: Powder charge inside a shot shell or cartridge case
Pulverized glass: Tiny particles of glass produced by bullet impact
Radial fracture: Glass fracture radiating outwardly from the point of impact
Reenactment: Use of actors, animated figures, scale models, and/or mannequins to simulate an action or series of actions in a shooting incident
Revolver: Firearm that uses a revolving cylinder to hold/fire cartridges
Ricochet: Change in bullet direction of travel as a result of impact with a substrate

Ricochet crease: Indentation in a substrate as a result of a bullet or pellet striking a substrate and being deflected off

Ricochet mark: Mark with no discernible depth resulting from a bullet or pellet striking a substrate and being deflected off

Rifling twist: Rotation direction of bullet as a result of rifling (may be right or left, but usually right)

Sabot: Subcaliber device that allows a smaller caliber bullet to be fired in a larger caliber weapon

Safety glass: Vehicle windshield glass consisting of two sheets of glass with a piece of plastic cemented in between

Semiautomatic: Weapon action that requires the trigger to be pulled for each shot but reloads itself automatically

Shooting reconstruction: Development of a likely or probable sequence of events in a shooting incident

Shot accounting: Determining the number of shots fired and their resultant impact sites

Shot shell buffer: White or black granular material found in some shot shells to take up space/keep shot apart

Single base powder: Gunpowder consisting of nitrocellulose

Slug: Single projectile for a shotgun

Sodium rhodizonate: Chemical test for lead

Soot: Carbonaceous material from the combustion of gunpowder

Spin stabilization: Clockwise or counterclockwise rotation of a bullet produced by the rifling within the barrel of a firearm

Suicide by cop: Willful baiting of an officer into the use of lethal force by an individual intent on their own demise

Suppression: Reduction of the sound of discharge through some means (usually via a device affixed to the muzzle that slows down the expansion of gases from the combustion of the gunpowder)

Tempered glass: Glass with stress built in during manufacture to prevent sharp edges from being produced upon breakage

Trajectory: Path of a bullet or shot pellet in flight

Trajectory rod: Any type of plastic, metal, or wooden rod placed into bullet holes to help determine the trajectory of the responsible bullet

Yawing: Side-to-side motion of a bullet about its long axis as a result of loss of stabilization in flight

Zero-base protractor: Protractor used for trajectory determinations that has degree graduations beginning at the base

Appendix A: A Ballistics Fable

It was a cold morning in the Cap Rock country of West Texas with a light drizzle falling. The hunter was chilled to the bone. A few degrees colder and the snow would have started to fall. The top of the high hill was hidden by the mist.

Slowly, the hunter looked over the cliffs before sighting a trophy mule deer just below the mist line on a high cliff. He knew the deer had not seen him, and he knew it could not smell him because of the strong wind blowing down the valley from his left, which caused the rain to wet his left side. A high hill apparently blocked the wind from the deer, and the last ¾ of the distance between them. The hunter guesstimated the distance across the gorge between them at 300 yards and then another 300 yards up the hill. He thought the elevation angle to the deer was about 45°.

The hunter started to feel the excitement of the moment, forgetting to remove the piece of electrical tape he had placed over the muzzle of his 30-06 rifle to keep the moisture out. As he shouldered the rifle, the hunter remembered that he had failed to clean the barrel after sighting it in back at his home in the piney woods of East Texas. Strange what a person thinks of at a stressful moment.

He had sighted the gun in at 300 yards so he figured the 45° upward angle should be compensated for by raising the cross hairs about 4 inches above the deer's shoulder blade. Then he aimed 5 more inches higher to offset the gravity of the steep hill (9 inches total elevation of the cross hairs). At the last minute, he thought of the wind but figured he was okay since only about the first 200 yards were exposed to the 10 mph or so wind.

He inhaled deeply, maintained his point of aim, and slowly squeezed the trigger until the report of the 30-06 round could be heard echoing through the canyons.

What do you think happened to the deer?

Answer: The deer is still out there roaming about! (The shot would have been high merely as a consequence of shooting uphill, but the 9-inch elevation of the sights insured that the bullet went over the top of the animal.)

The cross wind would have been somewhat of an issue, causing some drift that should have been compensated for. Likewise, the rain would have some effect due to the increased density of the air (i.e., bullet drop—but probably not enough to compensate for the elevated departure). There would be no effect from not having cleaned the gun and no effect from the tape over the muzzle.

Appendix B: Ammunition Component and Related Terminology

Rule #1: Call it what it is (i.e., referring to every ammunition item as a “projectile” creates confusion and requires later inspection of the evidence item to determine what it actually is).

Bullet—Projectile portion of a cartridge typically consisting of lead, electroplated lead, or a lead inner core with a copper or brass skin (jacket).
- **Fired bullet**—Bullet with obvious signs of firing (i.e., rifling marks and/or damage/expansion)
- **Bullet core**—Inner lead core from which the jacket has separated (note: there will be no rifling marks present on the core, only on the jacket)
- **Bullet jacket**—Copper or brass outer skin of a jacketed bullet (fired bullet jacket will have rifling marks and damage/expansion visible)
- **Fragments** (i.e., bullet fragment, jacket fragment, core fragment)—obviously incomplete based on size and appearance
- **Shot pellets** (may be visibly damaged, if so, describe as such)

Slug—Lead projectile designed to be fired in a shotgun (as there is typically no rifling in a shotgun barrel, the slug will frequently have rifling cast into it to impart spin stabilization).

Unidentifiable metal fragment—Metallic fragment having no discernible bullet/pellet/slug characteristics (if the surface can be indented/scratched with the thumbnail and is dark gray, it is reasonable to refer to it as an “unidentifiable lead fragment”).

Cartridge—Complete (unfired) unit consisting of a cartridge case, powder charge, bullet, and primer (either rim fire or center fire).
- **Cartridge case**—May be fired (as indicated by firing pin impression and interior soot deposits) or unfired; this needs to be specified
- **Shotgun shell** or **shot shell**—If fired, there will be a firing pin impression and an open end absent of powder/pellets/slug—correctly referred to as “fired shot shell”
- **Shot cup**—Plastic component that holds the shot
- **Wad**—Plastic, paper, or fiber disk that separates the powder from the shot

GSR—General term that includes gunpowder residue AND primer residue (one really needs to make the distinction as to which is being referred to).

Powder particles—Visible residue on clothing or other inanimate articles.

Powder stippling—Abrasions (NOT burns!) on *skin* produced by gunpowder impact (postmortem stippling appears yellow-brown as opposed to antemortem reddish color).

Primer residue—Deposits of ultramicroscopic spheroid particles containing compounds of barium, antimony, and lead that result from firearms discharge.

Soot deposits—Dark residue ("smoke") resulting from gunpowder combustion (discharge).

Bullet wipe—Black soot/grease ring at the margins of bullet holes through inanimate objects.

Apps for Shooting Reconstruction

Name of App	Type of App	Features	Cost
Plumb Bob by Appsamuck	Virtual Plumb Bob	Glows green when level	Free
Angle Meter	As stated	Omni-directional	$0.99
Tilt Meter	As stated	Easy to read	$1.99
Anatomy Atlas by Argosy Publishing	3-D anatomical images	Totally rotatable and can be drawn on	$29.95
Easy Measure	Measure distances "How far, how wide, and how tall?"	Accurate to ±1 inch Video tutorial	~$2.00
Google Earth	Satellite views	Zoom, rotate, raise/lower	Free
Show My Street	Satellite views and simultaneous street level views	Can toggle back and forth between views	Free
Theodolite by Hunter Research	Essentially a Total Station	Provides position, altitude, and time data, and calculates distances and angles	$4.99
Theodolite User Manual	As stated	Pretty useful for anyone who is only an occasional user	Free
Winchester Ballistics	Provides external ballistics data	Useful only for Winchester ammo	Free
ATF Officer's Guide to Recovered FA	FA Identification Info.	Tracing Data, S/N location info	Free
Flash Light	As stated	Useful if all else fails	$0.99
Scientific Calculator	As stated	sin, cos, tan	$0.99

Bloodstain Evidence and Wound Characteristics in Shootings

- Blood spatter resulting from gunshots will typically include a range of stain diameters from about 0.1 mm to less than 1 mm (although occasionally some will be larger).
- True high-velocity impact spatter (HVIS) appears as a mist-like deposit consisting of stains less than 0.1 mm in diameter.
- HVIS from a gunshot has a conical distribution.
- Bloodstains similar in size/appearance to HVIS may result from aspirated/expirated blood, blood dripping into blood, and "fly specks."
- Aspirated/expirated blood may potentially be recognized by the presence of air bubbles and/or the enzyme amylase.
- Pseudo-HVIS may result from blood being sloughed-off airborne bloody tissue.
- Pseudo-HVIS may travel significant distances both forward and backward from the impact point that defy predicted behaviors.

- Perforating wounds produce both forward spatter (travels in bullet direction) and back spatter (travels back toward the weapon).
- Heavy clothing, hair, etc., can diminish/mask both forward and back spatter.
- Forward spatter is typically more voluminous compared to back spatter.
- Penetrating wounds can exhibit only back spatter because there is no exit wound.
- Studies indicate that back spatter may travel as far as about 6 feet horizontally.
- Forward spatter may travel significant horizontal distances.
- Blood may be deposited in the bore of the gun, particularly for contact or near-contact shots.
- Blood may be deposited on the gun and the shooter's hand, particularly for contact/near-contact shots.
- Entry wounds are not necessarily smaller than exit wounds depending on the anatomical location (i.e., underlying bone, muscle structure), caliber, bullet design, muzzle velocity, and muzzle-to-target distance.
- Entry wounds may often be distinguished from exit wounds (all else being equal) by the presence of a red abrasion ring about the margins of entry wounds.
- Entry wounds may be distinguished from exit wounds by a black smudge ring visible within the outer abrasion ring (all else being equal).
- Entry wounds through overlying clothing may be distinguished from exit wounds by the presence of blood/tissue deposition to a larger degree on the inside surface of the inner layer of clothing at the exit wound site.
- Entry wounds in human tissue are typically categorized according to muzzle-to-target distance (i.e., contact/near contact, intermediate range, distant).
- Contact/near-contact wounds typically show blackening in the wound track due to powder/soot deposition (i.e., little or no stippling).
- Contact/near-contact wounds typically show stellate tearing when there is underlying bone.
- If there is overlying clothing, stellate tearing is typically present.
- Intermediate-range wounds are categorized by the presence of stippling (if bare skin is exposed; otherwise, powder deposition will be visible on overlying garments).
- Distant shots result in only probable abrasion rings about the wound margins and possible smudge rings (bullet wipe); smudge rings are also possible on the outermost garment.
- Shored exit wounds result from areas of the body being supported (on floor, tight garments, etc.) at the point of exit and display red abrasion rings.

GSR

Definition

The term "GSR" actually refers to two entirely different components associated with firearms discharge—gunpowder residue and primer residue.

Gunpowder Residue

Nitrocellulose residue (single base) or nitrocellulose/nitroglycerin residue (double base) produced upon ignition of the powder charge in a cartridge or shot shell.

- **Soot/Smoke**—Carbonaceous residue resulting from complete burning
- **Partially burned powder particles**—Result of incomplete burning of the powder charge in a cartridge or shot shell
- **Unburned powder particles**—Particles that were not ignited when the cartridge or shot shell containing them was discharged

Gunpowder residue is used to establish an approximate firearm barrel muzzle-to-target distance based on the size and density of the powder particles and also on the presence/absence of soot/smoke deposits.

- **Powder particles striking inanimate objects**—Simply referred to as *gunpowder particles*
- **Powder particles striking skin**—Abrade the skin and/or get between the dermis and the epidermis and are referred to as *stippling* or *powder tattooing*

Distances traveled by each depend on size, shape, and velocity. A few general rules may be used in approximating muzzle-to-target distances by the scene investigator:

- **Soot/smoke**—Because of its low mass, it travels up to a maximum of about 12 inches.
- Powder particles are expected to be present on clothing, etc., out to about 4 feet (however, under the right conditions, a few particles may travel significantly further—i.e., 5, 10, even 20 feet).
- Stippling on skin is, by definition, indicative of an "intermediate range" shot. Actual test firing with the incident firearm and similar ammunition is required to establish distance (varies from less than 2 feet out to almost 4 feet depending on firearm/ammo).

Primer Residue

Typically consists of compounds of barium, antimony, and lead that explode upon firing pin/striker impact to ignite the powder charge.

- Indicative of (1) firing a gun (2) being in proximity to a gun discharge (3) handling a gun or (4) coming in contact with something having primer residue on it
- No longer being done by the Federal Bureau of Investigation Laboratory because of the "lack of probative value"
- Still has a potential value under the appropriate circumstances

Shooting Reconstruction Myth Busters

Myth	Fact
1. Bullet impacts can knock people down, spin them around, etc.	People may react in various ways but the laws of physics (Newton's third law of motion) apply.
2. Bullet paths through multiple targets are pretty much straight.	Each time a bullet strikes an object, deflection is likely.

(*Continued*)

Myth	Fact
3. Ricochet marks/creases provide little useful information.	Under the right conditions, not only directionality but land/groove ratio and twist may be determined.
4. Fired shot cups found at scenes are of little value.	Not only gauge but ammo brand, shot size, and maximum distance may be ascertainable.
5. Gunpowder explodes upon discharge.	Gunpowder burns, primers explode.
6. Powder stippling is another term for powder burns.	Stippling is an abrasion.
7. GSR is a singular term.	GSR is a combination of three things: (1) Gunpowder particles (2) Soot/smoke (3) Primer residue (Pb, Ba, Sb)
8. Primer residue testing of a suspect's hands is a waste of time.	Not under the right conditions.
9. Cartridge case locations cannot approximate shooter position.	Under the right conditions, they can be helpful.
10. Back spatter on the shooter's hand is expected in suicides.	Back spatter frequently is not seen in self-inflicted gunshots.

Shot Accounting

Definition

Reconciling the number of fired cartridge cases/bullets with the number of bullet impacts (to both animate and inanimate targets).

Basis

The loading status of involved weapon(s) before a shooting as opposed to the loading status after a shooting.

Potential Problem

1. Is the loading status before the shooting known/accurate?
2. Did any reloading take place during/after the shooting?

Caveat

"Assuming the loading status of the weapon was ___________, then the total number of shots fired by this firearm appears to be _____________."

Example: A Colt .45 Model 1911 is recovered at a shooting scene with a live round in the chamber and four live rounds in the magazine. Because the magazine capacity is seven and one additional round could be in the chamber, a total of eight rounds would be its capacity (generally expressed as 7 + 1). Because the pistol has 4 + 1 (five rounds), the maximum number of fired shots (excluding any reloading) is 8 − 5 = 3.

Accordingly, the investigator should look for three fired cartridge cases and three bullet impacts. Ultimately, three fired bullets should be recovered at the scene and/or autopsy.

Special Considerations

1. Firearms routinely kept at less than full capacity—Example: H&K MP-5. Per H&K, the MP-5 should not be fully loaded to lessen the likelihood of failure to feed properly.
2. Officer's firearms—The presumption is "fully loaded," but is that absolute?
3. Clean missed shot—There will be no sign of a bullet impact and probably no bullet recovered.
4. Bullet reentries—It can appear that there are multiple shots when only one bullet is actually responsible. The appearance of secondary entries (reentries) is frequently irregular-shaped/distorted and, thereby, indicative of what has taken place.
5. Nonbullet impacts/entries—Apparent bullet impacts and entry holes/defects should be examined closely for trace evidence (blood, hair, tissue, fibers, glass, paint, etc.) indicative of actually being bullet-sourced. Confirmation may result from carrying out chemical testing for copper and lead.
6. Two rounds/one impact/one entry—In rare instances, two (or possibly more) rounds are involved in an apparent single impact/entry site. Autopsy findings and/or careful scene inspections can usually resolve such questions.

The "Big 3," Blood Drying, and Time Line Development

Definitions

- **The Big 3**—Three indicators of time since death: rigor mortis, livor mortis (postmortem lividity), and algor mortis.
- **Time Line Development**—Using scene indicators and other time-sensitive information to establish a time line for a shooting incident.

Rigor Mortis

The stiffening of the body after death due to depletion of adenosine triphosphate (ATP) is called rigor mortis. After death, the consumption of ATP continues whereas the production ceases. Ultimately, actin and myosin filaments become permanently complexed and rigor mortis sets in.

- Usually appears 2–4 hours after death (speeds up with antemortem exercise, begins with smaller muscles such as jaw).
- Fully develops in 6–12 hours.
- Disappears with decomposition.
- Cadaveric spasm gives the appearance of instantaneous rigor mortis.
- May appear faster with infants and slower with emaciated persons.

Livor Mortis

A reddish purple coloration in dependent areas of the body because of accumulation of blood in the small vessels due to gravity.

- Dependent areas resting against a firm surface appear pale (blanched)
- Usually evident 30 minutes to 2 hours after death
- Becomes fixed after 8–12 hours
- Actually more important for showing repositioning after death than time of death

Algor Mortis

The use of a formula to determine time of death based on postmortem temperature.

- Assumes body temperature was "normal" at death and that cooling was uniform.
- Neither assumption can be uniformly relied on.

Blood Drying

Finding dried bloodstains at a shooting scene typically indicates the passage of approximately 1 hour, assuming an ambient temperature of approximately 25°C and no unusual circumstances. Finding dried pools of blood indicates substantially more time has passed.

Appendix C: Scientific Working Group on Bloodstain Pattern Analysis—Recommended Terminology

Objective|Introduction|Statement of Purpose|Recommended Terminology

Objective

This document provides a recommended list of terms to use when teaching, discussing, writing, or testifying on bloodstain pattern analysis (BPA).

Introduction

The Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN) comprises BPA experts from North America, Europe, New Zealand, and Australia. SWGSTAIN provides a professional forum in which practitioners in BPA and related fields can discuss and evaluate methods, techniques, protocols, quality assurance, education, and research. SWGSTAIN's ultimate goal is to use these professional exchanges to address substantive and operational issues within the field of BPA and to build consensus-based, or "best practice," guidelines for the enhancement of the discipline of BPA.

Statement of Purpose

SWGSTAIN has developed and defined a list of recommended terminology for use in BPA. In developing this list, SWGSTAIN reviewed terminology in use across BPA.

Recommended Terminology

Accompanying Drop: A small blood drop produced as a by-product of drop formation.
Altered Stain: A bloodstain with characteristics that indicate a physical change has occurred.
Angle of Impact: The acute angle (alpha), relative to the plane of a target, at which a blood drop strikes the target.
Area of Convergence: The area containing the intersections generated by lines drawn through the long axes of individual stains that indicates in two dimensions the location of the blood source.
Area of Origin: The three-dimensional location from which spatter originated.
Back Spatter Pattern: A bloodstain pattern resulting from blood drops that traveled in the opposite direction of the external force applied; associated with an entrance wound created by a projectile.

Blood Clot: A gelatinous mass formed by a complex mechanism involving red blood cells, fibrinogen, platelets, and other clotting factors.

Bloodstain: A deposit of blood on a surface.

Bloodstain Pattern: A grouping or distribution of bloodstains that indicates through regular or repetitive form, order, or arrangement the manner in which the pattern was deposited.

Bubble Ring: An outline within a bloodstain resulting from air in the blood.

Cast-Off Pattern: A bloodstain pattern resulting from blood drops released from an object because of its motion.

Cessation Cast-Off Pattern: A bloodstain pattern resulting from blood drops released from an object because of its rapid deceleration.

Directional Angle: The angle (gamma) between the long axis of a spatter stain target and a defined reference line on the target.

Directionality: The characteristic of a bloodstain that indicates the direction blood was moving at the time of deposition.

Drip Pattern: A bloodstain pattern resulting from a liquid that dripped into another liquid, at least one of which is blood.

Drip Stain: A bloodstain resulting from a falling drop that formed due to gravity.

Drip Trail: A bloodstain pattern resulting from the movement of a source of drip stains between two points.

Edge Characteristic: A physical feature of the periphery of a bloodstain.

Expiration Pattern: A bloodstain pattern resulting from blood forced by airflow out of the nose, mouth, or a wound.

Flow Pattern: A bloodstain pattern resulting from the movement of a volume of blood on a surface due to gravity or movement of the target.

Forward Spatter Pattern: A bloodstain pattern resulting from blood drops that traveled in the same direction as the impact force.

Impact Pattern: A bloodstain pattern resulting from an object striking liquid blood.

Insect Stain: A bloodstain resulting from insect activity.

Mist Pattern: A bloodstain pattern resulting from blood reduced to a spray of microdrops as a result of the force applied.

Parent Stain: A bloodstain from which a satellite stain originated.

Perimeter Stain: An altered stain that consists of the peripheral characteristics of the original stain.

Pool: A bloodstain resulting from an accumulation of liquid blood on a surface.

Projected Pattern: A bloodstain pattern resulting from the ejection of a volume of blood under pressure.

Satellite Stain: A smaller bloodstain that originated during the formation of the parent stain as a result of blood impacting a surface.

Saturation Stain: A bloodstain resulting from the accumulation of liquid blood in an absorbent material.

Serum Stain: The stain resulting from the liquid portion of blood (serum) that separates during coagulation.

Spatter Stain: A bloodstain resulting from a blood drop dispersed through the air because of an external force applied to a source of liquid blood.

Splash Pattern: A bloodstain pattern resulting from a volume of liquid blood that falls or spills onto a surface.

Swipe Pattern: A bloodstain pattern resulting from the transfer of blood from a blood-bearing surface onto another surface, with characteristics that indicate relative motion between the two surfaces.

Target: A surface onto which blood has been deposited.

Transfer Stain: A bloodstain resulting from contact between a blood-bearing surface and another surface.

Void: An absence of blood in an otherwise continuous bloodstain or bloodstain pattern.

Wipe Pattern: An altered bloodstain pattern resulting from an object moving through a preexisting wet bloodstain.

Index

A

Adenosine triphosphate (ATP), 46, 462
AFIS, *see* Automated fingerprint identification system
Algor mortis, 463
Ammunition component and related terminology, 457–463, *see also* Firearms and ammunition components
  apps for shooting reconstruction, 458
  big 3, blood drying, and time line development, 462–463
    algor mortis, 463
    blood drying, 463
    definitions, 462
    livor mortis, 463
    rigor mortis, 462
  bloodstain evidence and wound characteristics in shootings, 458–459
  GSR, 459–460
    definition, 459
    gunpowder residue, 459–460
    primer residue, 460
  high-velocity impact spatter, 458
  rule #1 (call it what it is), 457
  shooting reconstruction myth busters, 460–461
  shot accounting, 461–462
    basis, 461
    caveat, 461
    definition, 461
    potential problems, 461
    special considerations, 462
  terminology, 1–6
Angle gauge, 107, 109, 144
Apps, *see* Smart phone/pad apps for shooting reconstruction
Architectural information, 406–407
ATF's Police Officer's Guide to Recovered Firearms (app), 152
ATP, *see* Adenosine triphosphate
Automated fingerprint identification system (AFIS), 190

B

Backyard ingenuity, product of, 132
Ballistics, 373–399
  case studies, 394–398
    case requiring external ballistics study, 395–398
    circumstantial case, 395
    defense theory, 396
    homicide case involving a suppressor, 394–395
    prosecution theory, 396
    Remington round bullet drop, 397
    trial, 396–397
  external ballistics, 381–387
    bullet drop, 384
    bullet efficiency, 383
    bullet path, 385
    bullet strike point, 386
    bullet velocity, 384
    calculus, 381
    destabilization characteristics of bullet, 382
    environmental effects, 386
    example, 382–383
    gravitational acceleration, 381
    kill zone, 382
    standard bullet, 383
    temperature, 386
    terminology, 382
    time of flight, 385
    uphill–downhill trajectories, 386
    wind drift, 385
  fable, 455
  internal ballistics, 373–381
    ballistic coefficient, 383
    barrel length, 378
    black powder revolver, 376
    boat tail bullet, 380
    cartridge case opening for primer flame, 375
    centerfire cartridge with primer in metallic cup, 374
    chamber sealing case expansion, 373
    events, 377
    expansion ratio, 381
    firearm discharge, 374
    flake-type gun powder particles, 376
    gun powder considerations, 376–381
    internal pressure curve, 378
    maximum velocity, 378
    modern centerfire cartridges, 374
    obturation, 373
    powder chamber capacity, 376–377

    - sawed-off barrels, weapons having, 381
    - smokeless powder, 375
    - spin stabilization of bullet, 379
    - standard bullet, concept of, 383
    - typical modern metallic centerfire cartridge, 375
    - unorthodox illustration of principles, 381
    - variables affecting, 377
    - weapon functioning, 377
  - sound suppressors, 392–394
    - improvised suppressors, 393
    - main source of sound, 393
    - makeshift sound suppressors, 393–394
    - “Maltese cross” interference figure, 393
    - potato suppressor, 393
    - Ruger semiautomatic pistol, 394
    - starch–iodine color test, 393
  - terminal ballistics, 387–392
    - bullet deflection study, 391
    - gelatin block studies, 389, 390
    - immediate incapacitation, 388
    - misconceptions, 390–392
    - permanent cavity, 388
    - principle of the two Ps, 388
    - pristine bullet, 392
    - temporary cavity, 388
    - terminology, 387
    - tissue crushing, 388
    - witness panel, 391
- Bazooka recoil, 16
- Best fit oval, 69, 101, 291
- Big 3, 462–463
- Birdshot, 91, 175
- Bloodstains and blood spatter at shooting scenes, 287–310
  - back spatter, 287, 288
  - blood characteristics and drop formation, 287–293
    - adhesive force (blood on finger), 293
    - aged blood that has blackened, 290
    - analogy, 293
    - basic bloodstain shapes, 291
    - basic facts, 287–291
    - best-fit oval, 291
    - impact angle and stain shape, 291
    - plasma, 287
    - serum separation, 290
    - stain length measurement, 292
    - stain width measurement, 292
    - surface effects, 290
  - bore scopes, 296
  - case study, 303–307
    - close-up of chair blood, 306
    - defense reenactment, 304
    - hypothesis confirmed, 307
    - police reenactment, 304
    - pseudo-impact blood spatter, 303–307
  - exercises, 308–310
  - firearms injuries, blood spatter associated with, 293–296
    - close-range shots, 295
    - forward and back spatter, 296
    - head shot to suicide bomber, 294
    - impact spatter from a beating, 294
    - large caliber handgun, 295
    - wound types, 295
  - forward spatter, 289
  - gun and hand, blood on, 288
  - hands of the shooter, blood on, 297
  - high velocity impact spatter, 297
  - locating latent bloodstains, 307–308
  - nongunshot dynamics that can mimic high-velocity impact blood spatter, 299–301
    - expiratory blood, 300, 301
    - fly specks, 300, 301
    - satellite spatters, 299
  - objects at the shooting scene, blood on, 298–299
    - blood pools, information provided by, 298
    - distance versus diameter, 299
    - misconception, 298
    - questions, 298
  - time line development, blood and its use in, 301–303
    - considerations, 302
    - lividity, 302, 303
    - spattered blood clots, 302
    - time for blood to dry, 302
  - weapons, blood on/in, 296
- Bluetooth capability (laser measuring devices), 127
- Boat tail bullet, 380
- Body model, 435
- Buck shot, 91, 175, 260
- Bullet hole and wound characteristics, 223–257
  - case study, 251–252
  - clothing and underlying tissue, bullet holes in, 223–230
    - bullet entry/exit basics, 223–225
    - bullet wipe, 227
    - characteristics of bullet holes, 229
    - contact/near-contact shots, 227
    - cotton cloth, 225, 226
    - distant shots, 227
    - documentation, 250
    - human tissue, 228
    - intermediate range, 226, 227
    - muzzle imprint, 228
    - muzzle-to-target distance, 227
    - polyester cloth, 226
    - powder deposition, 229
    - powder stippling, 228
    - shored exit wound, 229
    - stippling, 230

- documentation, 249–251
  - bullet holes in clothing, 250
  - graze wound to chest, 250
  - pathologist, 249
  - photographs, 251
  - protocol, 249
  - sketches, 250
- exercises, 253–255
- glass, bullet holes in, 235–246
  - bullet fragmentation upon impact with glass, 244
  - bullet hole in windshield glass documentation, 245
  - case, 241
  - concentric fractures, 236
  - conchoidal fracture lines, 239
  - evidence glass properly marked, 239
  - fracture lines, 235
  - glass evidence checklist, 246
  - glass injuries, 241, 242
  - high-speed photograph, 243
  - modern glass, manufacture of, 235
  - moving vehicles, 237
  - perforation of windshield, 245
  - plate glass, 235
  - point of impact determination, 241
  - radial fractures, 236
  - safety plate glass, 235
  - shot order in glass, 236
  - spalling, 238
  - tempered glass, 237, 238
  - tin float process, 235, 238
  - Wallner lines, 240
  - windshield glass, 236, 243
- lead and copper detection kit, 224
- reconciling bullet holes in clothing with underlying wounds, 231–235
  - folds in jeans, 234
  - graze wounds, 232
  - in–out–in–out series of bullet holes in outer left leg of jeans, 234
  - mannequin, 232, 233
  - Trayvon Martin case, 231–232
- sheet metal, bullet hole in, 224
- tires and other elastic materials, bullet holes in, 247–249
  - cautious approach, 247
  - hollow point bullets, 247, 248
  - misleading appearance, 248
  - pursuit tire, 249
  - shots into metal and plastic, 249
  - test firings, 249
  - visible scuff ring from hollow point bullet perforation, 247

Bullet ricochet, *see* Ricocheting bullets

Bullet wipe, 227

C

CAD software, *see* Computer-aided design software

CADZone, 404, 405

Caliper app, 147

Camera equipment for shooting reconstruction, 135–137
- close-up of bullet impact, 140
- distant photo of bullet impact, 139
- intermediate photo of bullet impact, 139
- photography rules, 136
- representative photographs, 138–140
- ring flash, 135, 137
- scales, 138
- single lens reflex digital camera, 135, 137

Carpenter–plumber syndrome, 45

Cartridge case ejection pattern testing for semiautomatics, 155–166
- exercises, 164–165
- interpretation of results, 164
- methodology, 161–164
  - average ejection angle, 163
  - cartridge case ejection pattern, 163
  - ejection pattern setup, 162
  - Pythagorean theorem, 163
  - tripod, 162
- testing considerations, 155–161
  - ammunition type, 156
  - argument, 156
  - cartridge case ejection, 156
  - case, 158
  - chronograph, 160
  - “gangsta” style of holding a weapon, 157
  - net ejected cartridge case velocity, 160
  - obstacles within shooting scene, 161
  - rearward velocity component, 160
  - scenario, 159, 160
  - usefulness of cartridge case locations, 158
  - weapon design, 155
  - weapon position, 157

Case analysis, 341–371
- general case analysis examples, 357–370
  - body as found by first responders, 357
  - Break-Free solvent, 361
  - case 1 (accidental shooting or homicide), 357–364
  - case 2 (homicide or suicide), 364–370
  - detectives, 358
  - gunpowder particle, 362
  - investigation structure, 359
  - questionable lividity, 364
  - results of examinations, 360
  - sequence of events, 369–370
- general considerations, 341–344
  - case, 342
  - common mistake, 341

        - high stress situations, 341
        - holistic approach, 341
        - mental state, 343
        - scene diagram, 343
        - time frames, 342
    - homicide versus suicide issues, 352–353
        - absence of evidence, 352
        - GSR test results, 352
        - misconceptions, 352
        - self-inflicted gunshot, 353
    - off-scene analysis of crime scene data, 351–352
        - cartridge case analysis, 351
        - overhead view of trajectory, 352
        - photographic images, 351
        - side view of trajectory, 351
        - steps, 351
    - participant information to obtain, 353–354
        - hearing acuity, 354
        - important information, 353–354
        - visual acuity, 354
    - recognizing staged/misrepresented crime scenes, 348–350
        - drop tests, 350
        - fingerprints, 350
        - indicators, 349
        - postmortem lividity, 349
        - video camera 350
    - shot accounting, 344–348
        - autopsy photo showing probable trajectory, 346
        - casing, 347
        - chart, 348
        - confusion, 347
        - deformed bullet, 347
        - descriptions, 346–347
        - determining the number of shots fired, 344
        - fired cartridge cases, 347
        - officer's magazine contents, 345
        - Q1 bullet, 348
        - terminologies, 346
        - typical scenario, 347
    - shots fired into vehicles, 354–357
        - angular coordinates, 355
        - linear coordinates, 355
        - overhead view of trajectory in truck bed, 3556
        - scale drawings, 357
        - side view of trajectory in car body panel, 355
        - vehicle bullet hole documentation and trajectory analysis, 356–357
        - windshield, shot to, 354
- CCSEM–XRF, *see* Computer-controlled scanning electron microscopy coupled with XRF
- Charts and graphs, 433
- Chemical testing, 208
- Chokes, 88, 174
- Chronographs, 130–132
    - cartridge case ejection pattern testing, 160
    - chronograph with intermediary target, 130
    - comparison firing, 131
    - cosmolene, 132
    - determination of cartridge case ejection velocity with, 160
    - example of chronograph being used to solve a case, 130–132
    - "hot" loads, 131
    - test firing, 131
- Circulatory collapse, 388
- Civil War miniballs, 80
- Clothing and underlying tissue, bullet holes in, 223–230
    - bullet entry/exit basics, 223–225
    - bullet wipe, 227
    - characteristics of bullet holes, 229
    - contact/near-contact shots, 227
    - cotton cloth, 225, 226
    - distant shots, 227
    - documentation, 250
    - human tissue, 228
    - intermediate range, 226, 227
    - muzzle imprint, 228
    - muzzle-to-target distance, 227
    - polyester cloth, 226
    - powder deposition, 229
    - powder stippling, 228
    - shored exit wound, 229
    - stippling, 230
- CODIS (Combined DNA Index System) database, 191
- Comparison firing, 131
- Compass app, 143–144
- Computer-aided design (CAD) software, 431
- Computer-controlled scanning electron microscopy coupled with XRF (CCSEM–XRF), 202
- Computerized animation, 44, 315, 316, 421
- Cosmolene, 132
- Courtroom presentation, *see* Report writing, demonstrative evidence, and courtroom presentation
- Court testimony, 428–429
- Crime laboratory results, maximizing, 443–448
    - failure to collect appropriate samples/controls, 447–448
        - case examples, 447–448
        - guiding principle, 447
        - search warrant, 447
    - failure to provide pertinent details, 446–447
        - case example, 446–447
        - laboratory report, 446
    - failure to request appropriate analyses, 443–444
        - case example, 443–445
        - laboratory manuals, 443
        - training, 443
    - familiar saying, 448
    - firearm workstation, 444
    - forensic chemist, 444

  gas chromatograph–mass spectrometer, 445
  infrared spectroscopy scan, 446
  laboratory instrumentation, 445
  reconstruction mentality, 448
Crime Scene Virtual Tour software, 409
Cut rifling, 81
Cylinder halo, 84

D

Databases, *see* Firearm/ammunition reference collections, databases, and software
DEA, *see* Drug Enforcement Administration
Deformed bullet, 347
Demonstrative evidence, *see* Report writing, demonstrative evidence, and courtroom presentation
DNA technology, 189, 191, 314
Double-action weapons, 77
Drawings, diagrams, and photographic images, 415–424
  bullet holes, 417
  close-up taken with tripod and remote shutter release, 417
  computerized animation, 421
  distant view with depth of view details, 416
  "end of tape" card, 423
  general considerations in shooting scene diagramming, 420–422
  general rules for shooting scene photography, 415–420
  general videotaping protocol for shooting scenes, 423–424
  oblique lighting, 418
  poster-size enlargements, 420
  side view of trajectory, 419
  top view of trajectory, 420
  videotapes of shooting scenes, 422
Drive-by shooting, 205
Drug Enforcement Administration (DEA), 167

E

Elastic materials, *see* Tires and other elastic materials, bullet holes in
Electronic measuring tools, 121
Environmental effects (on ballistics), 386
Equipment, *see* Shooting reconstruction equipment
Evidence, *see also* Trace evidence examination; Trial presentation and demonstrative evidence
  absence of, 189, 204, 352
  collection log, 4
  demonstrative, 430
  evaluation and documentation, *see also* Shotgun pattern testing and evidence evaluation
    off-scene, 35–37
    on-scene, 33–35
  footwear impression, 316
  inventory lists, 4
  photographing of, 416
  physical, 430
  tire tread impression, 317
  transitory, 34, 187
Examination/testing of weapons and ammunition components, 187–197
  accuracy determination, 194–195
    foolhardy attempt, 194
    JFK assassination, 194
    machine rest, 194
    physical limitations, 195
  exercises, 196
  rate of fire determination, 195–196
    nonautomatic weapon, 195
    reporting of results, 196
    subjective nature of testing, 195
trace evidence examination, 187–194
    absence of evidence, 189
    automated fingerprint identification system, 190
    blood/tissue, 188
    cases, 192–914
    CODIS (Combined DNA Index System) database, 191
    crucial error, 190
    DNA technology, 189, 191
    fingerprints, 189
    function testing, 191–192
    information provided by bullets found at scene, 188
    obvious cases, 191
    spontaneous discharge, 192
    transitory evidence, 187
    watchword, 190
Exercises
  bloodstains and blood spatter at shooting scenes, 308–310
  bullet hole and wound characteristics, 253–255
  cartridge case ejection pattern testing for semiautomatics, 164–165
  examination/testing of weapons and ammunition components, 196
  firearms and ammunition components, 97–98
  gunshot residue testing, 220–222
  officer-involved shootings, 338–339
  ricocheting bullets, 279–284
  shooting reconstruction equipment, 137–142
  shooting reconstruction myth busters, 28–29
  shotgun pattern testing and evidence evaluation, 182–186
  smart phone/pad apps, 154
  terminology (use and abuse), 10–13
  theory and practice, 49–52
Expansion ratio, 381
Expiratory blood, 300, 301

External ballistics, 381–387
  bullet drop, 384
  bullet efficiency, 383
  bullet path, 385
  bullet strike point, 386
  bullet velocity, 384
  calculus, 381
  destabilization characteristics of bullet, 382
  environmental effects, 386
  example, 382–383
  gravitational acceleration, 381
  kill zone, 382
  standard bullet, 383
  temperature, 386
  terminology, 382
  time of flight, 385
  uphill–downhill trajectories, 386
  wind drift, 385

F

Federal Tactical 00 Buckshot round, 167, 172
Fingerprints, 189, 350
Firearm/ammunition reference collections, databases, and software, 401–411
  architectural information, 406–407
    CD-ROM, 406
    database, 406
    site-specific information, 407
  crime scene software, 409, 410–411
  imagery, 409–410
    computerized animations, 410
    Crime Scene Virtual Tour software, 409
    panoramic images, 409
  vehicle information, 403–406
    CADZone human forms, 405
    CADZone vehicle sketches, 404
    pickup truck, 403
  weapons/ammunition, 401–403
    databases, 402
    no gun case, 403
    potpourri, 402
    public access website, 401
    recalls and warnings, 402
  weather and meteorological data, 407–409
    ambient lighting conditions, 407
    case, 408
    precipitation, 407
    Show My Street image, 409, 410
    streetlight locations, 408
    websites, 407
Firearms and ammunition components, 75–98
  ammunition components, 89–93
    battery cup, 91
    bird shot, 91
    blunt nose, round nose, hollow point, 90
    buck shot, 91
    cartridge and fired bullet, 89
    case designs, 91
    disassembled buckshot shell, 92
    hand loads, 93
    primer cup, 91
    priming mixture, 90
    shot comparison diameters, 91
    shot shell, 91
    slug, 91
    through-and-through shot, 93
  exercises, 97–98
  firearms categories and nomenclature, 75–86
    blunt nose Winchester, 86
    case, 83–84
    cutaway of barrel with left twist, 83
    cut rifling, 81
    cylinder flares, 84
    cylinder notch, 85
    double-action weapons, 77
    early handguns, 79
    examples, 76
    fully automatic weapons, classification of, 78
    halos, 84
    handguns, 75
    hollow point Federal, 86
    long guns, 75, 79
    miniballs, 79, 80
    pistol actions, 77
    polygonal rifling, 81
    revolver actions, 77, 84
    rifling characteristics, 82
    rifling process, 80
    semiautomatic weapons, 77
    single-action weapons, 77
  scene documentation of weapons, 94–96
    case, 95
    chamber contents, 95
    Glock, 94
    Kimber, 94
    loading diagram, 96
  special notes concerning firearms, 86–89
    handguns, 86–87
    rifles, 88
    shotguns, 88
    submachine and machine guns, 89
Flashlight app, 151
"Fluff versus substance" test (report writing), 415
Fly specks, 300, 301
Footwear impression evidence, 316
Forensic garbage collector, 32
Fully automatic weapons, classification of, 78

G

"Gangsta" style of holding a weapon, 157, 354
Gas chromatograph–mass spectrometer (GC-MS), 445
GC-MS, *see* Gas chromatograph–mass spectrometer

Gelatin block studies, 389, 390
Glass
  bullet holes in, 235–246
    bullet fragmentation upon impact with glass, 244
    bullet hole in windshield glass documentation, 245
    case, 241
    concentric fractures, 236
    conchoidal fracture lines, 239
    evidence glass properly marked, 239
    fracture lines, 235
    glass evidence checklist, 246
    glass injuries, 241, 242
    high-speed photograph, 243
    modern glass, manufacture of, 235
    moving vehicles, 237
    perforation of windshield, 245
    plate glass, 235
    point of impact determination, 241
    radial fractures, 236
    safety plate glass, 235
    shot order in glass, 236
    spalling, 238
    tin float process, 235, 238
    Wallner lines, 240
    windshield glass, 236, 243
  ricochets off, 268–270
  safety plate (windshields), 235
  tempered, 237, 238
Global positioning system (GPS), 146
Glock trigger safety, 318
Glossary, 449–453
Google Earth, 152
Google Maps, 433
GPS, *see* Global positioning system
Graphs, 433
Gravitational acceleration, 381
Graze wounds, 232, 250
Griess test, 208, 210
GSR, *see* Gunshot residue
Gunshot residue (GSR), 23–25, 199, 459–460
  cases, 24, 25
  definition, 459
  evaluation, 24
  forms, 23
  gunpowder residue, 23, 459–460
  misunderstanding of term, 7
  myth, 23, 25
  off-scene evaluation and documentation, 36
  primer residue, 23, 460
  sample collection, 24
  sniper shooting, 25
  testing, *see* Gunshot residue testing
Gunshot residue testing, 199–222
  case study, 218–220
    possible shot orientation (but improbable), 220
    stippling on the back of the victim's right hand, 219
    victim at morgue after clean-up, 219
    victim at scene, 218
  collection of GSR from fixed inanimate objects, 212–213
    Griess test, 213
    procedure, 212–213
    sodium rhodizonate test, 213
    test paper, 213
  determination of time since discharge, 217–218
  exercises, 220–222
  GSR sources, 199
  muzzle-to-target distance approximation testing (human tissue), 213–217
    angular shot with semiautomatic pistol, 214
    asymmetrical soot deposits produced by angular shots, 214
    case, 215–216
    headrest with bullet entry-exit, 216
    Kraft paper, 213
    laser termination, 217
    powder stippling on skin (through clothing), 215
    stippling, 213
    trajectory determination, 216
  muzzle-to-target distance approximation testing (inanimate objects), 206–212
    bullet hole in cloth, 207
    chemical testing, 208
    Griess test, 208, 210
    GSR orientation, 211
    gunpowder particle on skin, 206
    handgun powder, 206
    infrared film, 208
    rifle powder, 206
    rule of thumb, 207
    sodium rhodizonate test, 209
    soot residue, 210
    test firings, 207
  "paraffin" test, 217
  persistence of primer residue, 199–200
  primer residues and shooter determination, 200–205
    absence of evidence, 204
    cases, 204–205
    CCSEM–XRF, 202
    drive-by shooting, 205
    environmental sources, 205
    laboratory analysis, 202
    primer residue particle, SEM image of, 202
    sampling for primer residues, 200–201
    scanning electron microscopy, 201
    time frame, 203
    unique particles, 203
    x-ray fluorescence spectroscopy, 201
  talcum powder, 199
  ultimate GSR, 200

H

Halos, 84
Heart, massive disruption of, 388
High velocity impact spatter (HVIS), 297, 458
Hollow point bullets, cookie cutter effect, 248
Homicide versus suicide issues, 352–353
  absence of evidence, 352
  GSR test results, 352
  misconceptions, 352
  self-inflicted gunshot, 353
HVIS, *see* High velocity impact spatter

I

Immediate incapacitation, 388
Impact angles, calculation of, 62–66
Improvised suppressors, 393
Incident angle, template used to determine, 103
Infrared photography, 208
Infrared spectroscopy scan, 446
Instant Google Street View (app), 152
Intermediate range, 226
Internal ballistics, 373–381
  ballistic coefficient, 383
  barrel length, 378
  black powder revolver, 376
  boat tail bullet, 380
  cartridge case opening for primer flame, 375
  centerfire cartridge with primer in metallic cup, 374
  chamber sealing case expansion, 373
  events, 377
  expansion ratio, 381
  firearm discharge, 374
  flake-type gun powder particles, 376
  gun powder considerations, 376–381
  internal pressure curve, 378
  maximum velocity, 378
  modern centerfire cartridges, 374
  obturation, 373
  powder chamber capacity, 376–377
  sawed-off barrels, weapons having, 381
  smokeless powder, 375
  spin stabilization of bullet, 379
  standard bullet, concept of, 383
  typical modern metallic centerfire cartridge, 375
  unorthodox illustration of principles, 381
  variables affecting, 377
  weapon functioning, 377
INTERPOL, 403

J

JFK assassination
  argument to lone-gunman theory, 194
  reenactment, 40, 41
Jury, reliance on experts, 20

K

Kill zone, 382

L

Laser measuring devices, 127–128
  Bluetooth capability, 127
  Leica Disto D330i, 127
  Leica Sketch App, 127
  use of, 128
Law enforcement
  buckshot rounds designated for, 172
  bullet performance, 378
  databases made available to, 403
  firearm/ammunition reference collections, 401
  jargon, 6
  non-AFTE member of, 402
  popular round for, 393
  pursuit tire used by, 249
  shotguns issued to officers, 167, 174
  terminology adopted by, 1
  trigger travel, 319
Leica Disto D330i (laser measuring device), 127
Leica Sketch App, 127
Level app, 145
Lividity, 302, 349, 364, 425
Livor mortis, 463
Long guns, 75, 79

M

Machine guns, 78, 89
Machine rests, 132, 194
Magic bullet, 19
Maps (as evidence), 433
Martin, Trayvon (case), 231–232
Mathematics of shooting reconstruction, 55–74
  calculation of impact angles, 62–66
    case, 65–66
    hole length, 63
    hypothesis testing, 65
    impact angle, 63, 64
    shotgun pellet patterns, 64
    videotaped testing, 65
    warning shot, 66
  other calculations, 66–69
    best fit oval, 69
    bullets recovered, 68
    case, 69
    field of view, 67
    rate of fire, 66
    semiautomatic weapons, 66
    time of target availability, 67
  problems, 69–74
  trigonometry, geometry, and shooting incident analysis, 55–62

- acute angles, 58
- angles and sides of a triangle, 57
- calculation of building height, 59
- complementary angles, 55, 56, 58
- hypotenuse, 55, 56
- Pythagorean theorem, 57, 59
- right triangle, 55, 56
- sniper incident, 60
- standard right triangle, 58
- sum of angles in a triangle, 56
- supplementary angles, 55, 56
- triangle, 56
- trigonometric functions, 57

Measuring apps, 147–151
Minute of angle (MOA), 382
Misused terms, *see* Terminology (use and abuse)
MOA, *see* Minute of angle
Mockups, 434
"Mother of All Full-Scale Reenactments," 40
Muzzle-to-target distance, 227
- approximation, 173–176
- approximation testing (human tissue), 213–217
  - angular shot with semiautomatic pistol, 214
  - asymmetrical soot deposits produced by angular shots, 214
  - case, 215–216
  - headrest with bullet entry-exit, 216
  - Kraft paper, 213
  - laser termination, 217
  - powder stippling on skin (through clothing), 215
  - stippling, 213
  - trajectory determination, 216
- approximation testing (inanimate objects), 206–212
  - bullet hole in cloth, 207
  - chemical testing, 208
  - Griess test, 208, 210
  - GSR orientation, 211
  - gunpowder particle on skin, 206
  - handgun powder, 206
  - infrared film, 208
  - rifle powder, 206
  - rule of thumb, 207
  - sodium rhodizonate test, 209
  - soot residue, 210
  - test firings, 207

Myth busters, *see* Shooting reconstruction myth busters

N

NATO, *see* North Atlantic Treaty Organization
Newton's Third Law of Motion, 15–17
- bazooka recoil, 16
- bullets and, 15–17
- classic example, 16
- graphic video, 15
- recoil, 15

No gun case, 403
North Atlantic Treaty Organization (NATO), 374

O

Obturation, 373
Officer-involved shootings, 311–339
- accidental discharge of weapons, 323–324
  - armorer, 324
  - rarity of mechanical malfunctions, 323
  - weapon malfunction, 323
- case studies, 325–337
  - autopsy photo, 330
  - Charles Whitman and the University of Texas tower incident, 331–337
  - civil suit, 330
  - entry wound to neck, 330, 332
  - medical examiner's report, 328
  - officer with suspect, 326
  - probable case of suicide by cop, 325–330
  - uncooperative suspect, 327
- exercises, 338–339
- general considerations, 311–317
  - armorers, 314
  - bullet trajectory determination, 312
  - clothing, 317
  - computerized animation, 315, 316
  - DNA testing, 314
  - documentation of bloodstains, 317
  - ejection pattern testing, 314
  - fired cartridge case locations marked, 315
  - footwear impression evidence, 316
  - pre-impact bullet trajectory, 315
  - protocol, 311–317
  - sampling, 313
  - shotgun pellet pattern, 312
  - standard operating procedure, 311
  - tire tread impression evidence, 317
  - trigger pull determination, 314
  - weapon collection and loading status check, 312
- suicide by cop, 324–325
  - actions indicative of intent, 324–325
  - backgrounds of individuals, 325
  - case study, 325–331
  - circumstances, 325
  - indicators, 324
  - motivators, 325
  - probable case of, 325–330
  - synonymous terms, 324
- suspect shot in the back, question regarding, 337–338
- unintentional discharge of weapons, 318–323
  - case, 320–323
  - Glock trigger safety, 318

        - human error, 319
        - involuntary firing, 319
        - police-issue semiautomatic pistol, 318
        - sympathetic nervous response, 319
        - trigger pulls, 319
        - unintentional shootings, 319
- Off-scene evaluation and documentation, 35–37
    - case synopsis, 35
    - close-range shot, 36
    - gunshot residue, 36
    - interview, 35
    - off-scene issues, 36
    - suicide reenactment, 37
- 1-inch-to-1-yard rule, 175, 176
- On-scene evidence evaluation/documentation, 33–35
    - photographs, 34
    - protocol, 34
    - trace evidence, 34
    - transitory evidence, 34
    - verification, 33
- Overall summation report, 413

P

- "Paraffin" test, 217
- Pear effect (ricochet), 265–266
- Periodic Table of the Elements, live action version of (app), 152
- Permanent cavity, 388
- Photography, *see also* Drawings, diagrams, and photographic images
    - bullet holes in glass, 251
    - camera equipment for shooting reconstruction, 135–137
        - close-up of bullet impact, 140
        - distant photo of bullet impact, 139
        - intermediate photo of bullet impact, 139
        - photography rules, 136
        - representative photographs, 138–140
        - ring flash, 135, 137
        - scales, 138
        - single lens reflex digital camera, 135, 137
    - high-speed, 243
    - infrared film, 208
    - off-scene analysis of crime scene data, 351
    - on-scene evidence evaluation/documentation, 34
    - streetlight locations, 408
- Physical evidence, 430
- Pictometry, 433
- Plumb bob app, 143
- Police evidence collection log, 4
- Polygonal rifling, 81
- Potato suppressor, 393
- Powder chamber capacity, 376–377
- Powder stippling, 228
- PowerPoint presentations, 425–428
- Principle of the two Ps, 388
- Pristine bullet, 392
- Projectile syndrome, 2
- Pseudo-impact blood spatter, 303–307
- Pursuit tire, 249
- Pyrodex, 206
- Pythagorean theorem, 55, 59, 165

Q

- Q1 bullet, 348

R

- Ransom rest, 195
- Recoil, 15, 16
- Reconstruction mentality, 32, 448
- Reconstruction myths, *see* Shooting reconstruction myth busters
- Reenactment in shooting reconstructions, 38–47
    - carpenter–plumber syndrome, 45
    - case study, 43, 47
    - clotted blood, 46
    - computer animation, 44
    - dried/drying blood, 46
    - full-scale indoor reconstruction, 40
    - full-scale reenactments, 39–40
    - hypothesis testing, 43
    - JFK assassination reenactment, 40, 41
    - livor mortis (color of death), 46–47
    - "Mother of All Full-Scale Reenactments," 40
    - outdoor reenactment, 40
    - portable scale model, 43
    - rigor mortis (stiffness of death), 46
    - scale models, 40–42
    - time line development, 44–47
- Reference collections, *see* Firearm/ammunition reference collections, databases, and software
- Remington round bullet drop, 397
- Remington semiautomatic shotgun, 168
- Report writing, demonstrative evidence, and courtroom presentation, 413–441
    - court testimony, 428–429
    - drawings, diagrams, and photographic images, 415–424
        - bullet holes, 417
        - close-up taken with tripod and remote shutter release, 417
        - computerized animation, 421
        - distant view with depth of view details, 416
        - "end of tape" card, 423
        - general considerations in shooting scene diagramming, 420–422
        - general rules for shooting scene photography, 415–420
        - general videotaping protocol for shooting scenes, 423–424

        oblique lighting, 418
        poster-size enlargements, 420
        side view of trajectory, 419
        top view of trajectory, 420
        videotapes of shooting scenes, 422
    full-scale reproductions, 424–425
        cardboard mockups, 424
        example, 424
        simulated pool of blood, 425
    PowerPoint presentations, 425–428
        court exhibits, 425
        courtroom presentations, 426
        postmortem lividity, 425
        reports and court testimony, 426–428
    report format, 413–415
        disclaimer, 414
        "fluff versus substance" test, 415
        glitch, 413
        overall summation report, 413
        suggested summation report format, 414–415
    trial presentation and demonstrative evidence, 429–440
        abdominal trauma, 431
        body model, 435
        charts and graphs, 433
        complex cases, 434
        computer-aided design software, 431
        demonstrative evidence, kinds of, 430–440
        evidence types, 430
        hypothesis testing, 434
        maps, 433
        methods, 429
        mockups, 434
        photograph, 430
        physical evidence, 430
        scale model, 434, 438
        scene diagram, 431
        trajectory mannequin, 440
        trial preparation tasks, 429
Reverse directionality phenomenon (ricochet), 263
Revolver actions, 77, 84
Ricocheting bullets, 259–285
    bullet and shot pellet, 21–22
    case study, 277–279
    conditions conducive to ricochets, 259–261
        buckshot ricochet off car door, 260
        bullet design and composition, 259
        high-velocity bullets, 259
        ricochet creases off sheet metal, 261
        spherical pellets, 261
    direction of twist determination from ricochet mark, 270–273
        lateral deflection of ricochet, 272
        left twist mark and right twist mark, 271
        photography, 272
        ricochet mark tail production, 270
        rifling marks, 271, 272, 273
    documentation, 276
    establishing critical angles, 273–274
        angle of impact, 274
        critical angle determination, 273, 274
        equipment required, 273
    establishing deflection angles, 275
    establishing ricochet angles, 274–275
        example, 274
        ricochet angle setup, 274
        witness panel, 275
    establishing shooter position, 276
    evidence that ricochet has occurred, 276–277
    exercises, 279–284
    indicators of directionality, 261–266
        classic ricochet mark, 264–265
        fracture lines in painted surfaces, 262–264
        pear effect, 265–266
        point of impact, 261
        reverse directionality phenomenon, 263
        shot directionality, 262
        V shape, 261–262
    ricochet crease profiles, 266–270
        internal ricochet, 267
        ricochet off glass, 268–270
        ricochet off sheet metal, 266
        ricochet with partial penetration, 267
        wafer board, 267
    ricochet terminology, 259
Rifling process, 80
Rigor mortis, 462
Ruger semiautomatic pistol, 394

S

Safety plate glass (windshields), 235
Scale model, 434, 438
Scanning electron microscopy (SEM), 201, 313
Scene diagram, 431
Science Glossary @ Vision Learning (app), 152
Scientific calculator app, 145
Scientific method, shooting reconstruction and, 31–33
    defining the problem, 32
    forensic garbage collector, 32
    formulating a theory, 32–33
    ignorance, 31
    making observations, 32
    methodical inquiry, 31
    modifying the theory as required, 33
    reconstruction mentality, 32
    testing the theory, 33
Scientific Working Group on Bloodstain Pattern Analysis (terminology), 465–467
SEM, *see* Scanning electron microscopy
Semiautomatics, *see* Cartridge case ejection pattern testing for semiautomatics
Shooting reconstruction equipment, 99–142

camera equipment for shooting reconstruction, 135–137
  close-up of bullet impact, 140
  distant photo of bullet impact, 139
  intermediate photo of bullet impact, 139
  photography rules, 136
  representative photographs, 138–140
  ring flash, 135, 137
  scales, 138
  single lens reflex digital camera, 135, 137
chronographs, 130–132
  chronograph with intermediary target, 130
  comparison firing, 131
  cosmolene, 132
  example of chronograph being used to solve a case, 130–132
  "hot" loads, 131
  test firing, 131
documentation of bullet holes at shooting scenes, 99–111
  angular components, 104, 106, 107
  "best fit oval," 101
  bullet hole measurement, 99
  digital calipers, 102
  distorted bullet hole in car door, 101
  hand lens, 100
  hole width measurement, 104
  incident (impact) angle calculation, 105–106
  photographic documentation, 99
  scaled photographs, 100
  special considerations, 108–110
  template used to determine incident angle, 103
  trajectory rods, 104
  windshield glass, 110, 111
exercises, 137–142
laser measuring devices, 127–128
  Bluetooth capability, 127
  Leica Disto D330i, 127
  Leica Sketch App, 127
  use of, 128
other equipment required, 119–127
  electronic measuring tools, 121
  key points to remember, 123–127
  lasers, strings, and adhesive dots, 122
  possible shooter positions, 126
  proper trajectory rod placement, 120
  rod "extension" via laser, 122
  sources of error in trajectory angle determinations, 125–126
  substrate considerations, 120
  uneven, curved surfaces, 120–121
  zero base protractor, 121
specialized fixtures for shooting reconstruction, 132–135
  backyard ingenuity, product of, 132
  cardinal rule, 132
  case, 134–135
  fixture construction, 134
  human factor, 132
  machine rests, 132
  Ransom Rest, removal of, 132, 133, 134
  rotatable target fixture, 134
  shooting table, 133
  theoretical concept, reliance on, 132
  weapon accuracy, 132
3-D laser scanners, 128–129
total data stations, 128
trajectory kit, 100
trajectory rods and their use at shooting scenes, 111–119
  angle gauge, 107, 109
  assortment, 113
  bullet holes basics, 116
  calculating angles and substrate thickness, 112
  case, 114–115
  color coding different calibers, 114
  correct placement of, 115
  eye for string attachment, 113
  holder, 118
  overhead view, 116
  side view, 115
  trajectory rod accessories, 118
  trajectory rod in place, 112
  types of trajectory rods, 116–118
  use of tube for trajectory analysis, 114
Shooting reconstruction myth busters, 15–29
  blood back spatter from gunshots, 27–28
    myth, 27
    study, 27–28
    suicide, 27
  bullet and shot pellet ricochets, 21–22
    ricochet creases, 22
    ricochet marks, 21
    rifling characteristics of barrel, 21–22
  cartridge case ejection, 25–27
    cases, 26, 27
    deranged student, 27
    ejected cartridge cases, 26
    evaluation, 25
    standard tactical position, 26
  exercises, 28–29
  gunshot residues, 23–25
    cases, 24, 25
    evaluation, 24
    forms, 23
    gunpowder residue, 23
    myth, 23, 25
    primer residue, 23
    sample collection, 24
    sniper shooting, 25
  intermediary targets, bullets and, 17–21
    bullet fragmentation, unpredictable nature of, 20

    - cases, 18, 19, 20
    - evaluation, 19, 20
    - expertise, 19
    - good brush guns, 17
    - jury ruling, 19
    - magic bullet, 19
    - training of field investigators, 18
  - Newton's Third Law of Motion, bullets and, 15–17
    - bazooka recoil, 16
    - classic example, 16
    - graphic video, 15
    - recoil, 15
  - shotgun wads, cups, and wrappers, 23
- Shot accounting, 344–348, 461–462
  - autopsy photo showing probable trajectory, 346
  - basis, 461
  - casing, 347
  - caveat, 461
  - chart, 348
  - confusion, 347
  - definition, 461
  - deformed bullet, 347
  - descriptions, 346–347
  - determining the number of shots fired, 344
  - fired cartridge cases, 347
  - officer's magazine contents, 345
  - potential problems, 461
  - process, 4
  - Q1 bullet, 348
  - special considerations, 462
  - terminologies, 346
  - typical scenario, 347
- Shotgun pattern testing and evidence evaluation, 167–186
  - angle of impact estimation, 176
  - approximating muzzle-to-target distance, 173–176
    - barrel length, 174
    - birdshot, 175
    - buckshot pattern, 175
    - chokes, 174
    - gauge, 174
    - intermediary targets, 176
    - 1-inch-to-1-yard rule, 175
    - pellet size, 174
    - variables, 174
  - birdshot round, 169
  - buckshot rounds, 170, 172
  - distorted pellets, 167
  - exercises, 182–186
  - Federal Tactical 00 Buckshot round, 167
  - graphical analysis, 178
  - Remington semiautomatic shotgun, 168
  - reporting of results, 180
  - shot shell buffer and distance estimation, 178–180
    - buffer examples, 179
    - buffer morphologies, 179
    - case, 180–181
    - evidence photographs, 181–182
    - polyethylene buffer, 180
    - standard buffer, 180
  - slug round, 169
  - test firings, 169, 177–178
  - Winchester semiautomatic shotgun, 168
- Showmystreet.com (app), 152
- Show My Street image, 409, 410
- Silencers, *see* Sound suppressors
- Simpson, O.J. (case), 49, 50
- Single-action weapons, 77
- Single lens reflex digital (SLRD) camera, 135, 137
- SLRD camera, *see* Single lens reflex digital camera
- Smart phone/pad apps for shooting reconstruction, 143–154
  - all-in-one approach, 143
  - angle gauge app, 144
  - caliper app, 147
  - compass app, 143–144
  - exercises, 154
  - flashlight app, 151
  - global positioning system app, 146
  - Google Earth, 152
  - level app, 145
  - measuring apps, 147–151
  - other useful specialty apps, 152
    - ATF's Police Officer's Guide to Recovered Firearms, 152
    - Instant Google Street View, 152
    - Periodic Table of the Elements, live action version of, 152
    - Science Glossary @ Vision Learning, 152
    - Showmystreet.com, 152
    - Texas Code of Criminal Procedure, 152
    - Visible Body® Atlas, 152
    - Winchester Ballistics, 152
  - other visual aids, 153
  - plumb bob app, 143
  - scientific calculator app, 145
  - virtual laser protractor app, 147
- Sniper incident, 60, 114, 128
- Sodium rhodizonate test, 209, 213
- Software, *see* Firearm/ammunition reference collections, databases, and software
- Sound suppressors, 392–394
  - improvised suppressors, 393
  - main source of sound, 393
  - makeshift sound suppressors, 393–394
  - "Maltese cross" interference figure, 393
  - potato suppressor, 393
  - Ruger semiautomatic pistol, 394
  - starch–iodine color test, 393
- Spalling, 238
- Staged/misrepresented crime scenes, 348–350
- Starch–iodine color test, 393

Stippling, 213
Submachine guns, 78, 89
Suicide
  bomber, 294
  evidence of, 27
  homicide versus, 352–353
  reenactment, 37
Suicide by cop, 324–325
  actions indicative of intent, 324–325
  backgrounds of individuals, 325
  case study, 325–331
  circumstances, 325
  indicators, 324
  motivators, 325
  probable case of, 325–330
  synonymous terms, 324

T

Tempered glass, 237, 238
Temporary cavity, 388
Terminal ballistics, 387–392
  bullet deflection study, 391
  gelatin block studies, 389, 390
  immediate incapacitation, 388
  misconceptions, 390–392
  permanent cavity, 388
  principle of the two Ps, 388
  pristine bullet, 392
  temporary cavity, 388
  terminology, 387
  tissue crushing, 388
  witness panel, 391
Terminology (use and abuse), 1–13
  ammunition components, 1–6
    bullet, 2
    cartridges, 2
    fired bullet, 5
    fired cartridge case, 2
    fired shot shell, 4
    importance of using proper terminology, 2
    jargon, 6
    misused terms, 1
    police evidence collection log, 4
    projectile syndrome, 2
    see-through 12 ga shot shell, 3
    shot accounting process, 4
    terminology issues, 5
    training, 4
    unidentifiable lead fragment, 5
  exercises, 10–13
  firearms, 8–9
    accidental discharge, 9
    inappropriate terms, 8
    misused phrase, 9
    trigger pull, 9
    videotaped interview, 9
  other misused terms, 9
  rule #1 (call it what it is), 7–8, 457
    lack of understanding, 8
    misunderstood term, 7
    powder burn, 8
    terminology, 7
Texas Code of Criminal Procedure (app), 152
Theodolite app, 149
Theory and practice of shooting reconstruction, 31–53
  case study, 48–49
  exercises, 49–52
  goal of shooting reconstruction, 37–38
    complexity of processes, 37
    disciplines, 37
    scenario development, 37
    sequence of events, 38
  limitations of shooting reconstructions, 38
  off-scene evaluation and documentation, 35–37
    case synopsis, 35
    close-range shot, 36
    gunshot residue, 36
    interview, 35
    off-scene issues, 36
    suicide reenactment, 37
  on-scene evidence evaluation/documentation, 33–35
    photographs, 34
    protocol, 34
    trace evidence, 34
    transitory evidence, 34
    verification, 33
  other body indicators, 47
  other scene indicators, 48–49
  reenactment in shooting reconstructions, 38–47
    carpenter–plumber syndrome, 45
    case study, 43, 47
    clotted blood, 46
    computer animation, 44
    dried/drying blood, 46
    full-scale indoor reconstruction, 40
    full-scale reenactments, 39–40
    hypothesis testing, 43
    JFK assassination reenactment, 40, 41
    livor mortis (color of death), 46–47
    “Mother of All Full-Scale Reenactments,” 40
    outdoor reenactment, 40
    portable scale model, 43
    rigor mortis (stiffness of death), 46
    scale models, 40–42
    time line development, 44–47
  scientific method, shooting reconstruction and, 31–33
    defining the problem, 32
    forensic garbage collector, 32
    formulating a theory, 32–33
    ignorance, 31

    making observations, 32
    methodical inquiry, 31
    modifying the theory as required, 33
    reconstruction mentality, 32
    testing the theory, 33
3-D laser scanners, 128–129
Time line development, 301–303, 462
  considerations, 302
  lividity, 302, 303
  spattered blood clots, 302
  time for blood to dry, 302
Tin float process, 235, 238
Tires and other elastic materials, bullet holes in, 247–249
  cautious approach, 247
  hollow point bullets, 247, 248
  misleading appearance, 248
  pursuit tire, 249
  shots into metal and plastic, 249
  test firings, 249
  visible scuff ring from hollow point bullet perforation, 247
Tire tread impression evidence, 317
Tissue crushing, 388
Trace evidence examination, 187–194
  absence of evidence, 189
  automated fingerprint identification system, 190
  blood/tissue, 188
  cases, 192–914
  CODIS (Combined DNA Index System) database, 191
  crucial error, 190
  DNA technology, 189, 191
  fingerprints, 189
  function testing, 191–192
  information provided by bullets found at scene, 188
  obvious cases, 191
  spontaneous discharge, 192
  transitory evidence, 187
  watchword, 190
Trajectory kit, 100
Trajectory mannequin, 440
Trajectory rods, 111–119
  angle gauge, 107, 109
  assortment, 113
  bullet holes basics, 116
  calculating angles and substrate thickness, 112
  case, 114–115
  color coding different calibers, 114
  correct placement of, 115
  determination of angular components using, 104
  eye for string attachment, 113
  holder, 118
  overhead view, 116
  photographs of, 136
  side view, 115
  trajectory rod accessories, 118
  trajectory rod in place, 112
  types of trajectory rods, 116–118
  use of tube for trajectory analysis, 114
Transitory evidence, 34, 187
Trial presentation and demonstrative evidence, 429–440
  abdominal trauma, 431
  body model, 435
  charts and graphs, 433
  complex cases, 434
  computer-aided design software, 431
  demonstrative evidence, kinds of, 430–440
  evidence, types of, 430
  hypothesis testing, 434
  maps, 433
  methods, 429
  mockups, 434
  photograph, 430
  physical evidence, 430
  scale model, 434, 438
  scene diagram, 431
  trajectory mannequin, 440
  trial preparation tasks, 429
Trigger pull determination, 314
Trigger travel, 319

U

Unintentional shootings, 319
University of Texas tower incident, 60, 128, 331–337
“Unloaded” guns, 319
Uphill–downhill trajectories, 386
U.S. Geological Survey, maps from, 433

V

Vehicles, shots fired into, 354–357
  angular coordinates, 355
  linear coordinates, 355
  overhead view of trajectory in truck bed, 3556
  scale drawings, 357
  side view of trajectory in car body panel, 355
  vehicle bullet hole documentation and trajectory analysis, 356–357
  windshield, shot to, 354
Videotaping protocol for shooting scenes, 423–424
Virtual laser protractor app, 147
Visible Body® Atlas (app), 152

W

Wafer board (ricochet), 267
Wallner lines, 240
Warning shot, 66
Weapons/ammunition reference collections, *see* Firearm/ammunition reference collections, databases, and software

Weapons examination, *see* Examination/testing of weapons and ammunition components
Weather and meteorological data, 407–409
Winchester Ballistics (app), 152
Winchester semiautomatic shotgun, 168
Wind drift, 385
Windshield
  angle of inclination, 356
  beveling on, 110
  bullet holes in, 111
  safety plate glass for, 235
  shot to, 354
Witness panel, 391
Wound characteristics, *see* Bullet hole and wound characteristics

X

X-ray fluorescence spectroscopy (XRF), 201
XRF, *see* X-ray fluorescence spectroscopy

Z

Zero base protractor, 121

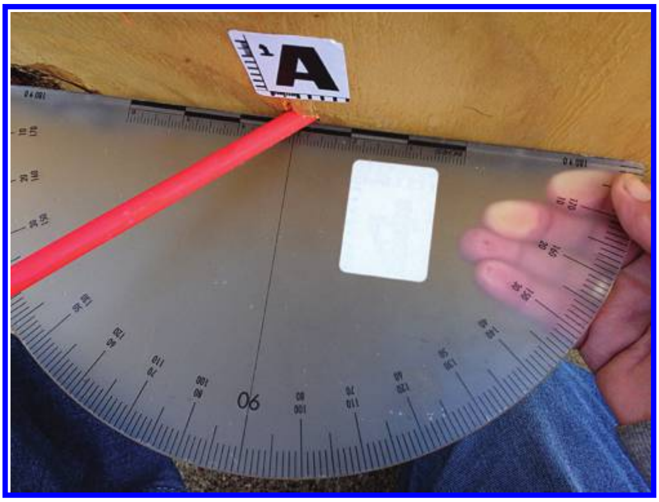

Figure 6.15 Measuring angle X with a protractor.

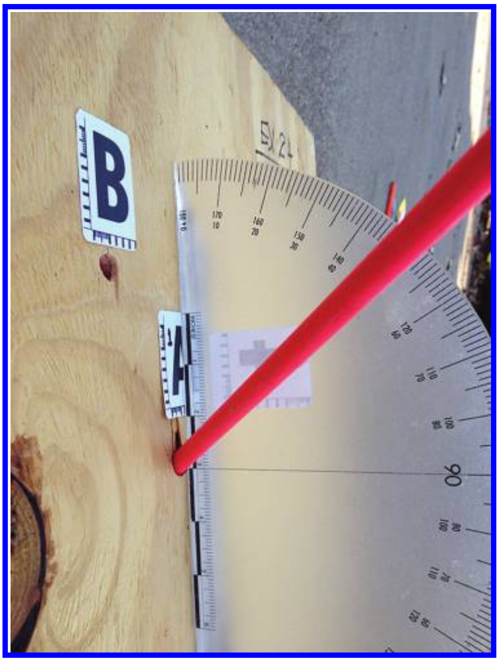

Figure 6.16 Measuring angle Y with a protractor.

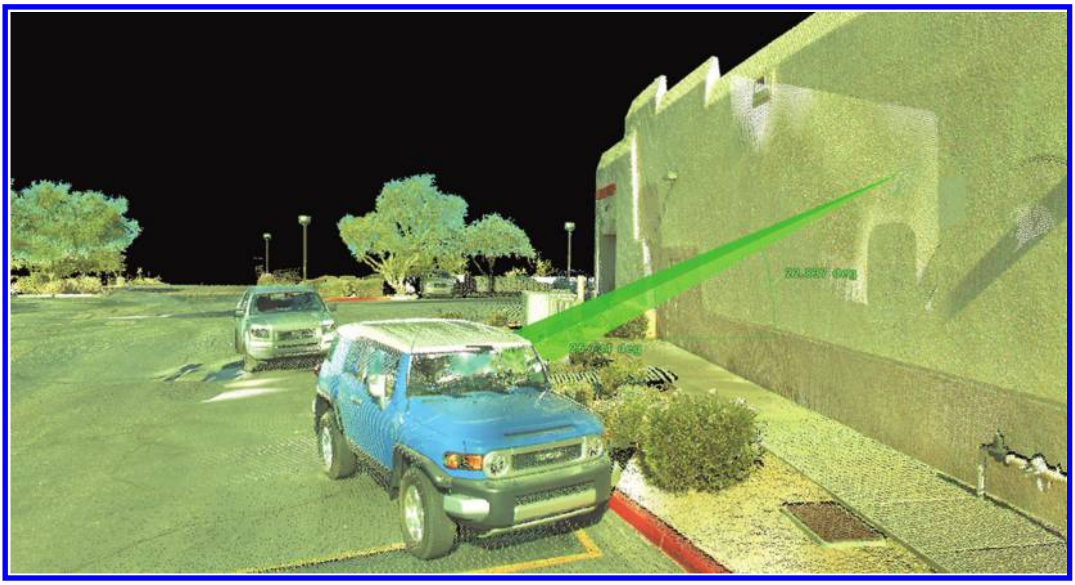

Figure 6.20 3-D laser scan by Michael G. Haag.

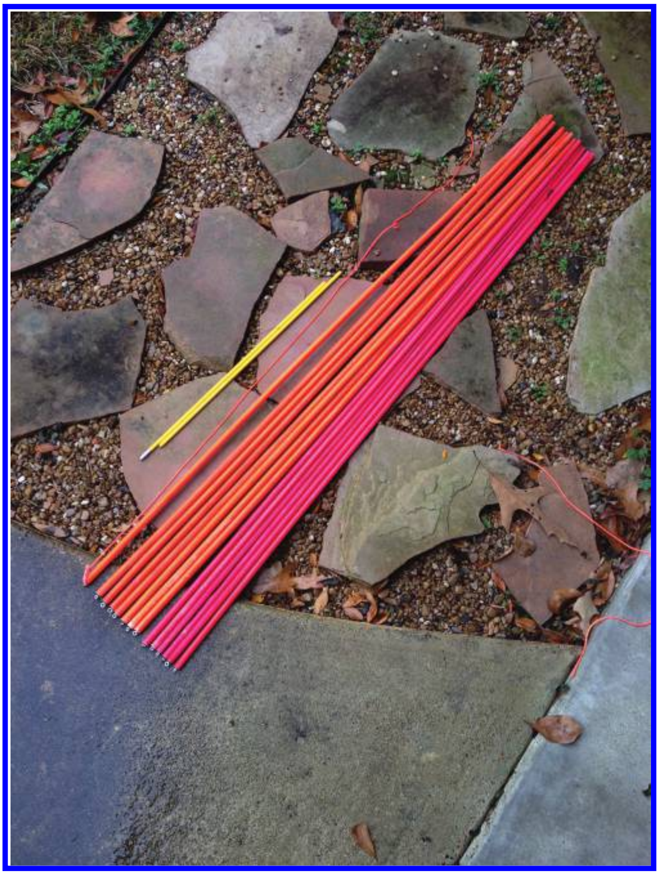

Figure 6.25 Color-coded trajectory rods (top 2 rods: 9 mm; middle 8 rods: 40 cal; bottom 6 rods: 45 cal).

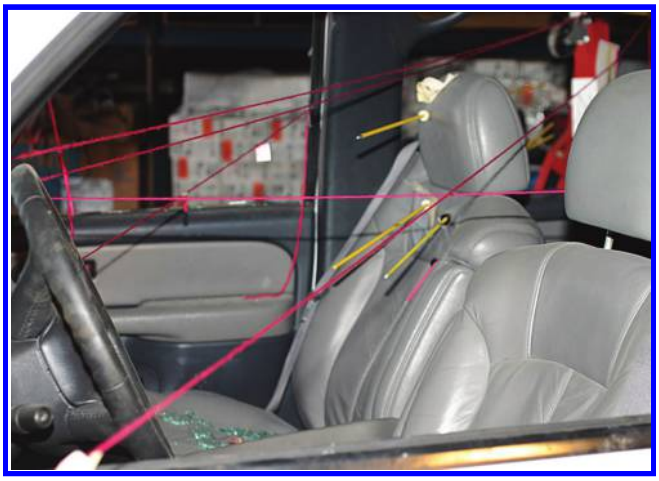

Figure 6.27 Color coding two different calibers.

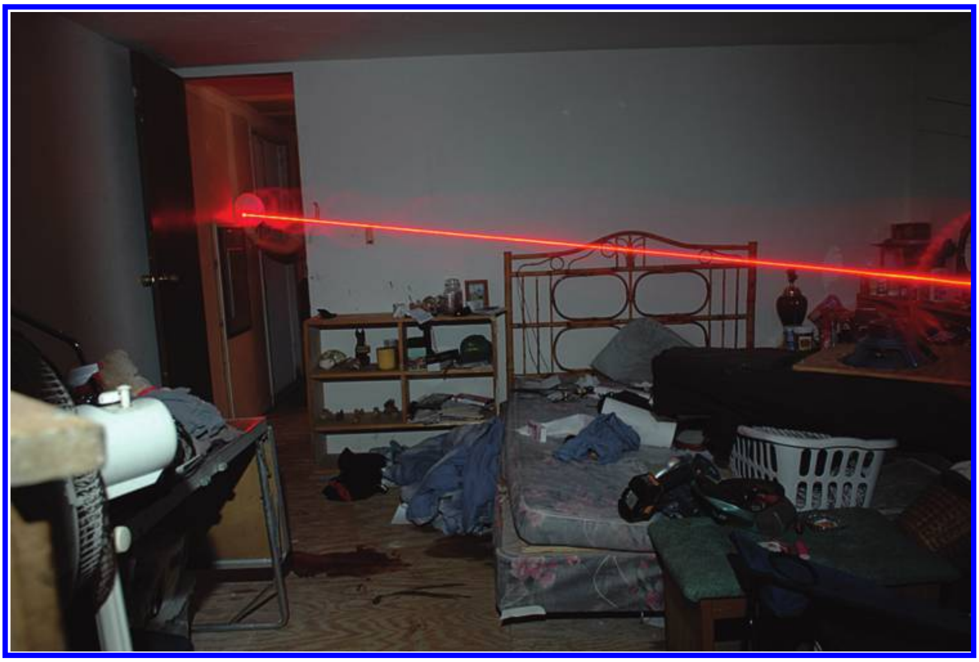

Figure 6.41 Scene photo of laser.

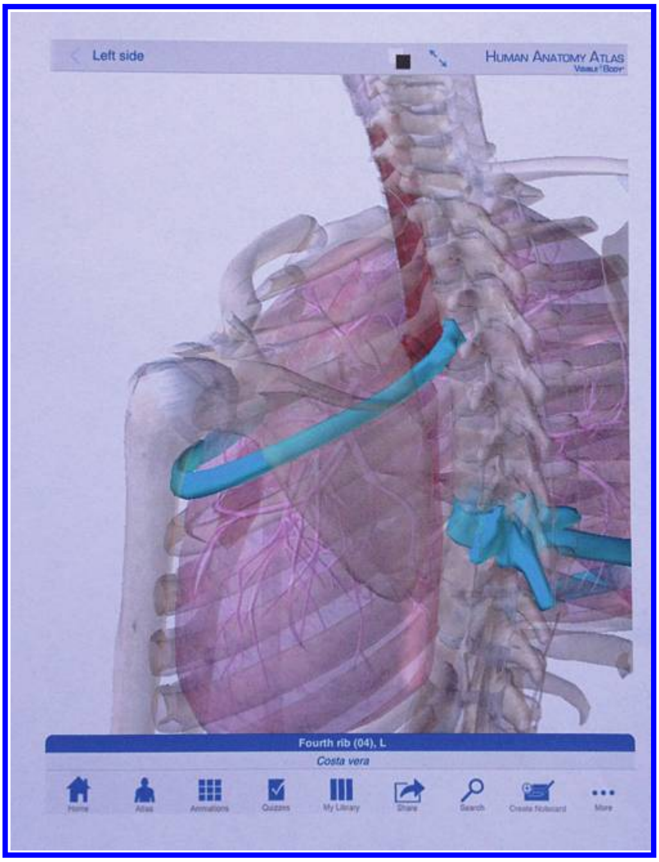
Left side
Human Anatomy Atlas
Visible Body
Fourth rib (04), L
Costa vera
Home
Atlas
Animations
Quizzes
My Library
Share
Search
Create Notecard
More

Figure 7.18 Visible Body image (bones impacted by bullet in blue).

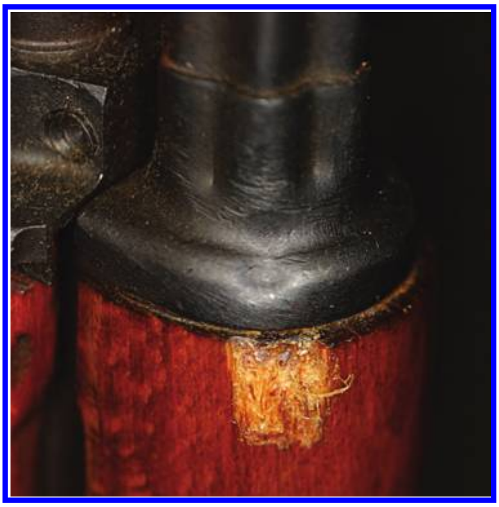

Figure 9.27 Indentations to metal and wood of AK-47.

Figure 11.1 Ultimate GSR (USS IOWA muzzle blast).

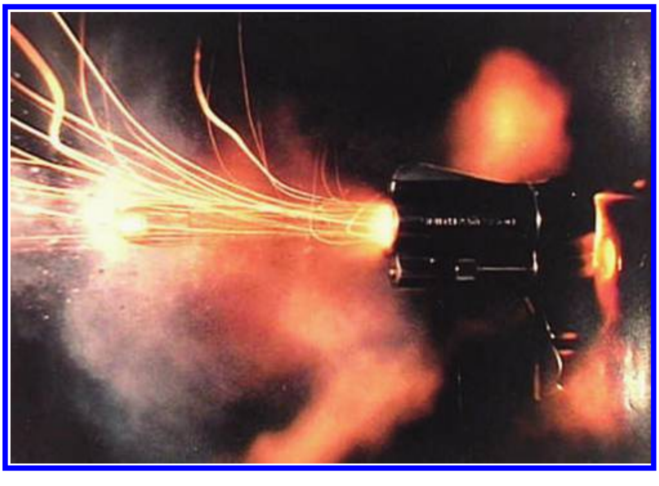

Figure 11.2 Typical revolver discharge products.

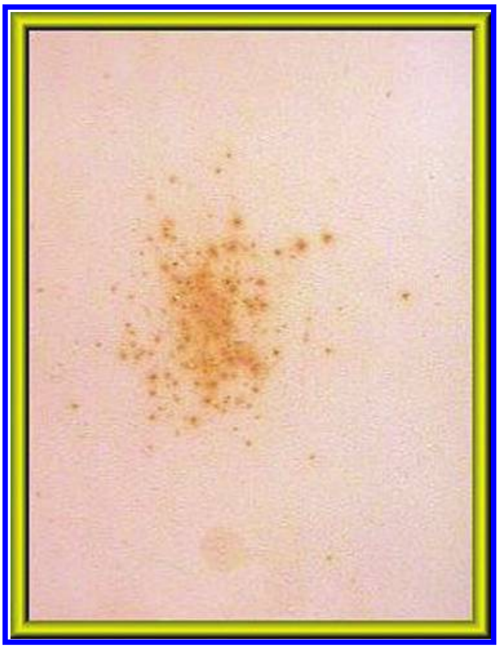

Figure 11.9 Griess test for nitrites.

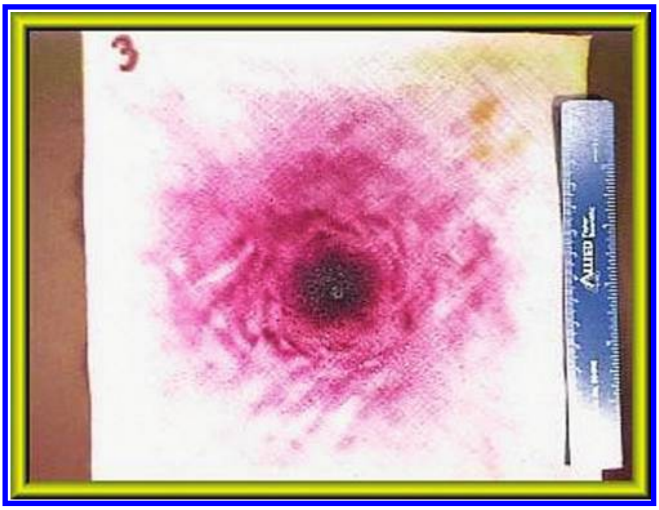

Figure 11.10 Sodium rhodizonate test for vaporous lead.

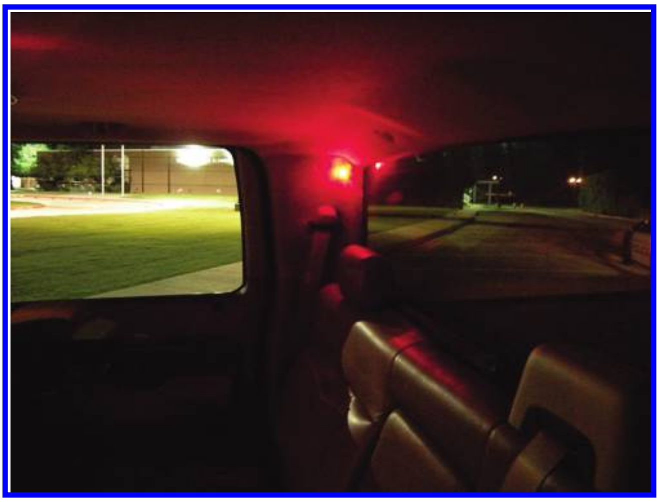

Figure 11.20 Laser termination.

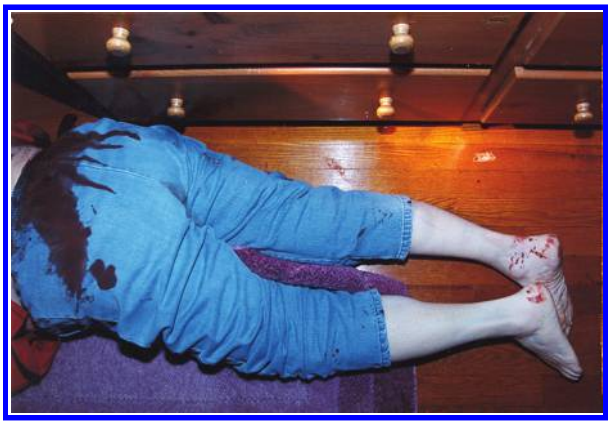

Figure 13.28 Ricochet crease in wood floor (between right calf and chest of drawers).

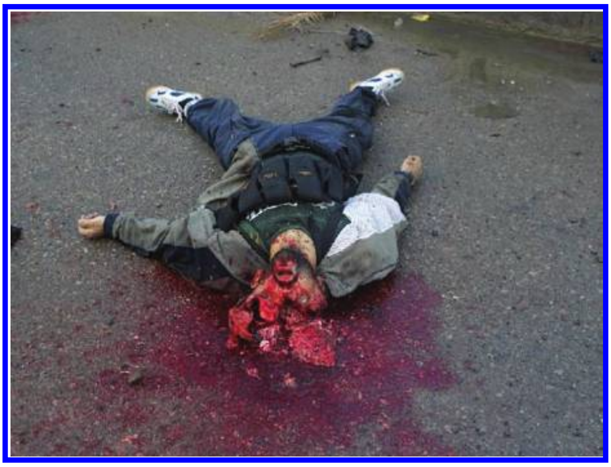

Figure 14.14 Head shot to a suicide bomber.

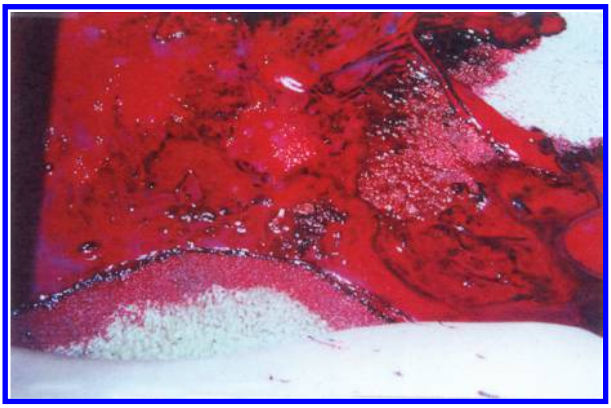

Figure 14.20 Pool of blood that has coagulated and is starting to dry (dark edges).

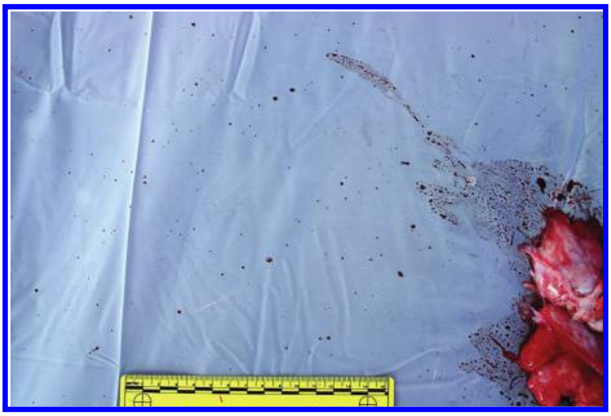

Figure 14.34 Pseudo–back spatter produced at 14 ft.

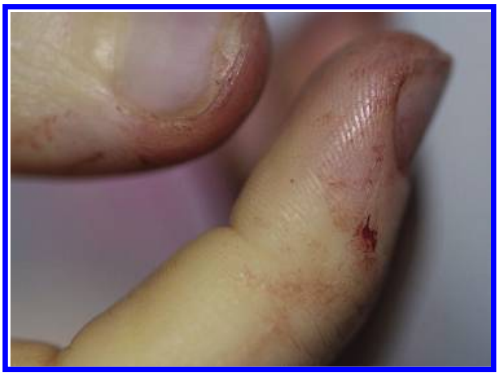

Figure 16.25 Bloodstain showing directionality (toward the finger tip).

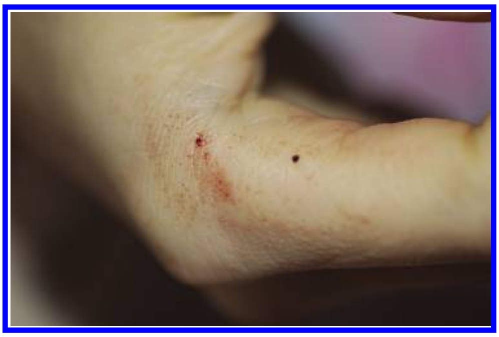

Figure 16.26 Possible gunpowder particle on hand.

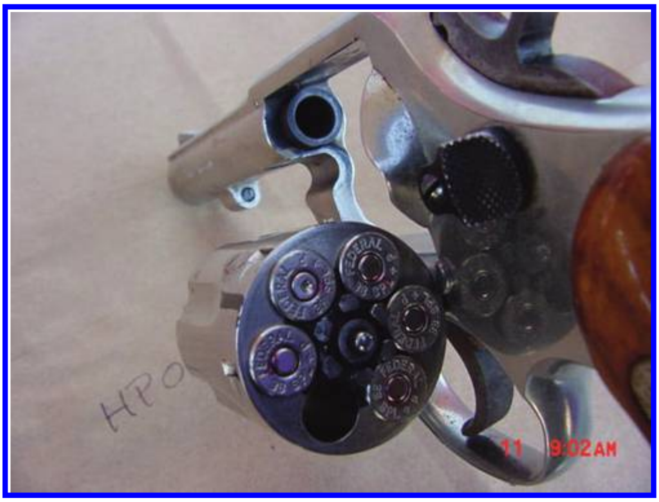
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Figure 16.36 Loading status (note the apparent blood on primer of cartridge to the left).

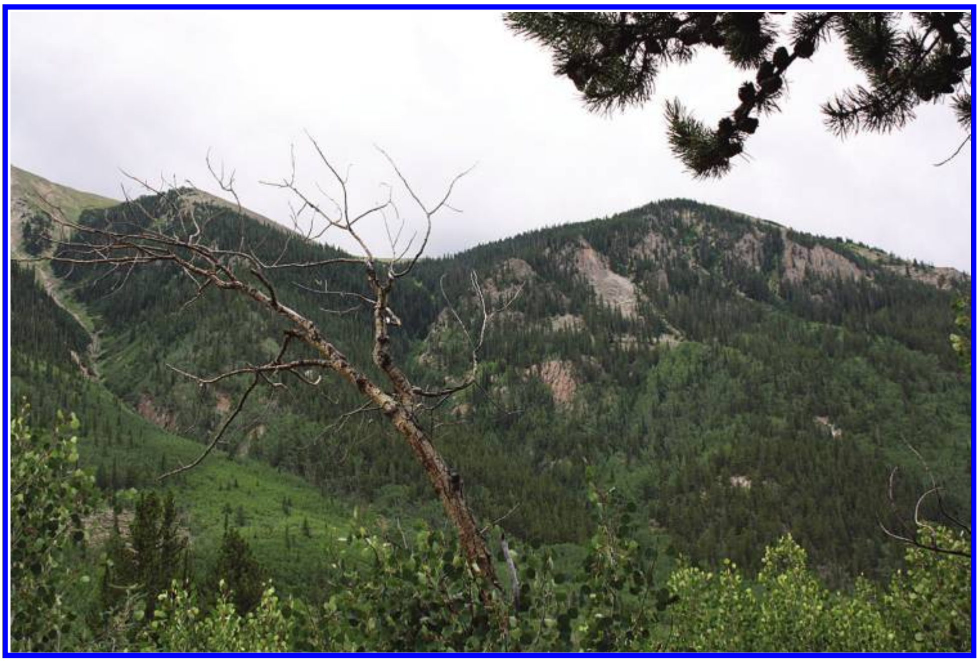

Figure 19.1 Distant view with depth of view details (branches).

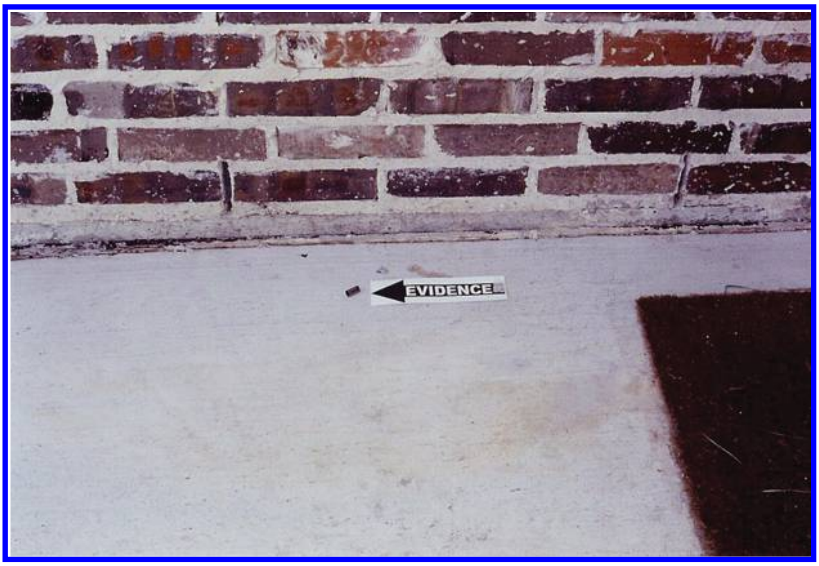

Figure 19.2 Cartridge case—intermediate distance.

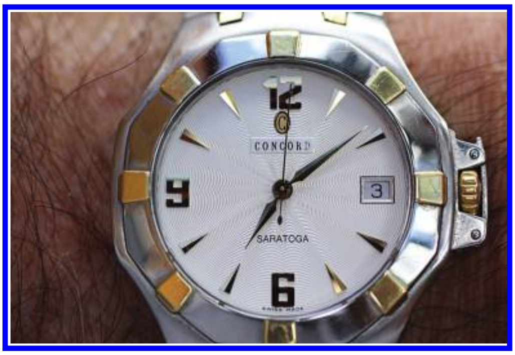
12
CONCORD
9
3
SARATOGA
6
SWISS MADE

Figure 19.3 Close-up taken with tripod and remote shutter release.

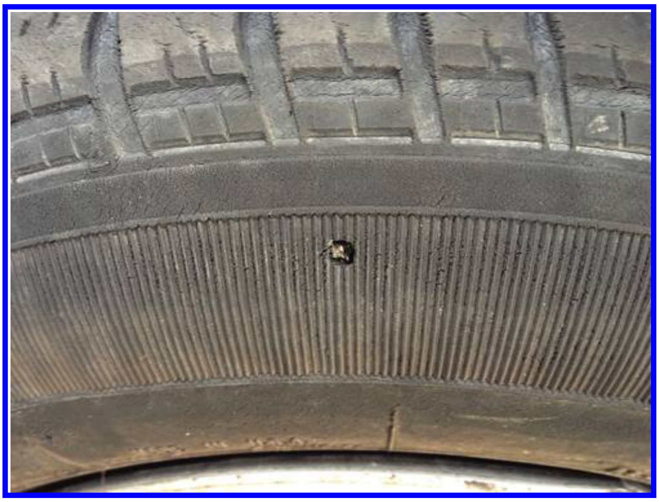

Figure 19.4 Bullet hole in tire sidewall (no scale).